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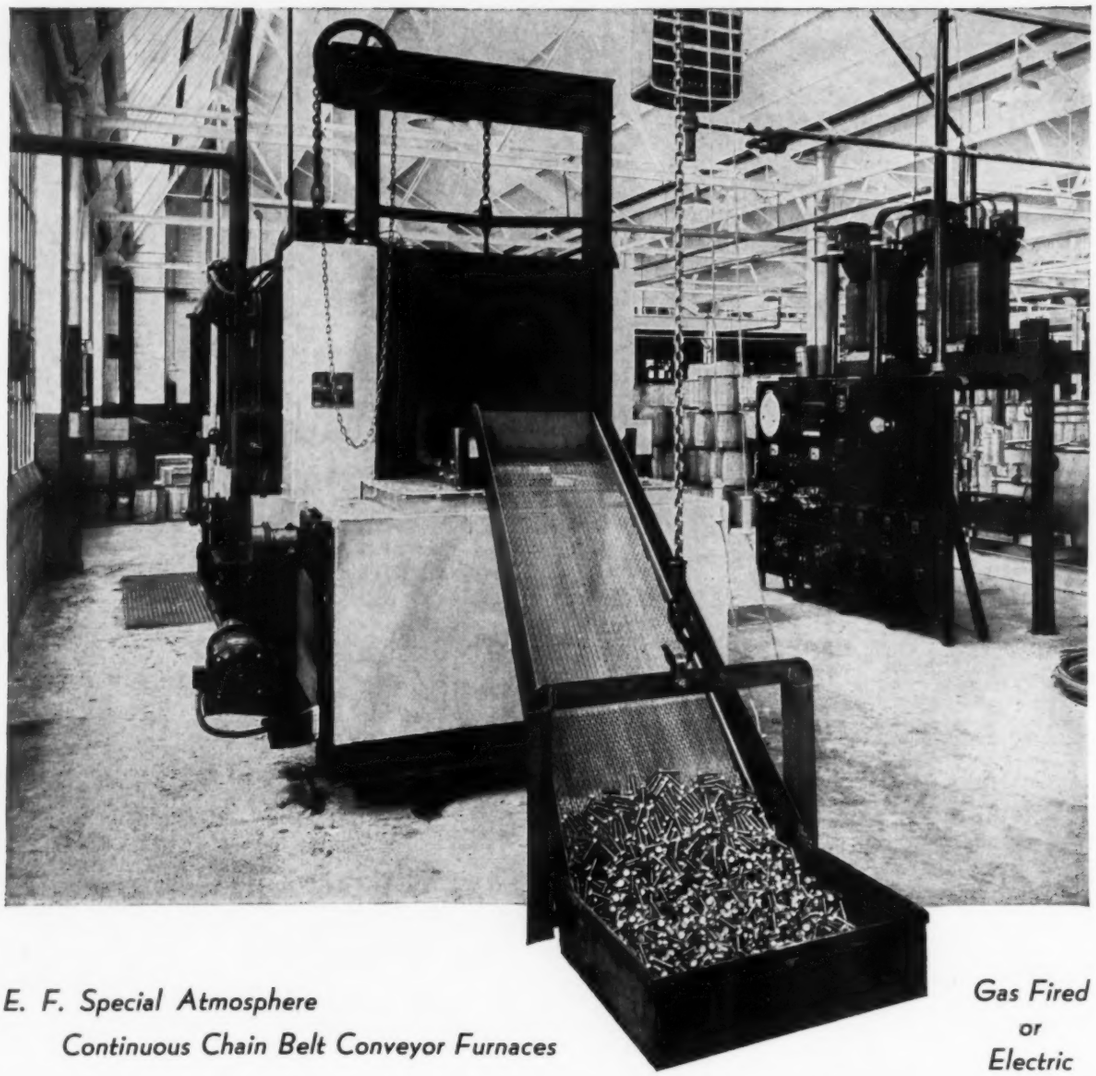

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POWER REQUIREMENTS of COLD STRIP Mills

Presented before the A. I. S. E.
35th Annual Convention,
Pittsburgh, Pa., Sept. 26-30, 1939

By A. F. KENYON, *Steel Mill Engineer*
WESTINGHOUSE ELECTRIC & MANUFACTURING CO.
EAST PITTSBURGH, PENNSYLVANIA

▲ WITHIN the last ten years, the cold reduction of steel strip has developed from a process used only for the small-scale finishing of certain specialized products, to its present status as the most important method of finishing all classes of flat rolled steel, including light gauges for tinplate, intermediate gauges for enameling and galvanized roofing stock, and heavy gauges for automobile body and fender sheets, etc. With this rapid development of equipment and operating practices, and the continuing installation of new mills and the modernization of existing mills, we believe that many members of the Association will be interested in power data which has been accumulated from a number of different cold mill plants, to indicate the performance which is being obtained on existing mills, and to guide the selection of equipment for new mills.

Detailed calculations are essential in the final determination of the ratings and characteristics of the electrical drive equipment for any proposed new mill, however comparison with the equipment installed on similar mills already in operation is frequently very helpful in making preliminary estimates, and also as a check on the later detail calculations. Tables I and II list most of the multi-stand tandem cold reduction strip mills which have been installed within the last seven or eight years, and for each mill there are listed the size of the mill rolls and reel, spacing between stands, ratings of mill and reel motors and main motor generator set, gear ratios, and mill speeds. Much of the data listed in these tabulations has previously been available in the published descriptions of the newer hot and cold strip mills, and we believe that the consolidation of the data to tabular form will prove convenient for reference and comparison.

Our discussion of the power requirements of cold strip mills will be presented in the following three main divisions:

1. A description of the steps in the preparation of energy consumption curves from test data, and their use to calculate the individual motor loads for some specified rolling schedule.
2. An analysis and comparison of typical energy consumption curves for rolling various strip products.
3. A listing of the mill output and kilowatt-hour energy consumption of several mills producing various classes of strip products.

PREPARATION OF TEST DATA

Most of the methods used for calculating the loads which will be imposed on the driving motors of a proposed mill when rolling a particular product at some specified rolling speed and making specified reductions in the individual passes, make use of test data observed from the operation of other mills of approximately the same size and type and rolling approximately the same product. To make this test data generally applicable it must be reduced to the basis of energy units per unit amount of rolling work, and plotted in the form of curves, from which may be read the values to apply to the particular conditions specified for the proposed new mill. Following is a brief description of the test data necessary, and the steps in the process of putting the data in curve form suitable for use in further power calculations.

Figure 1 shows a set of graphic meter charts taken from a five-stand tandem cold reduction strip mill while rolling a 4750 lb. coil of 26⅞ in. wide by .074 in. thick mild open hearth steel strip to .0094 in. thick strip for tinning, in five passes, and at 1425 ft. per min. final delivery speed. The fourteen charts show, respectively, the armature current in each of the mill and reel motors, the kilowatt input to the synchronous motor driving the main motor generator set, the speed of each of the mill motors, the main bus voltage which is the voltage applied to the mill motors, and the reel motor voltage which is higher than the main bus voltage because of a booster generator in the reel motor circuit. In this particular test this electrical power data was obtained by means of graphic meters, however quite as good data

TABLE I

FOUR-STAND AND FIVE-STAND TANDEM COLD REDUCTION TINPLATE MILLS

Nº	Company and Location	Year Installed	Roll Face	Diameter of: Work Rolls	Diameter of: Back Rolls	Diameter of: Reel Drum	Spacing: Between Stands	Spacing: Last Stand and Reel	Motors: Stand #1 HP	Stand #1 RPM	Stand #2 HP	Stand #2 RPM	Stand #3 HP	Stand #3 RPM	Stand #4 HP	Stand #4 RPM	Stand #5 HP	Stand #5 RPM	Reel HP	Reel RPM	Total HP	Main M.G. Set: Generators Kw	Generators Volts	Motor HP	Motor P.F.	Motor Volts	Motor Cycles	Motor RPM	Gear Ratio: Stand #1	Stand #2	Stand #3	Stand #4	Stand #5	Winding Reel	Roll F.P.M.: Stand #1	Stand #2	Stand #3	Stand #4	Stand #5
1	Inland Steel Co. Indiana Harbor	1934	40	18	49	24⅞	13'-0"	10'-6"	625	500/800	938	800/900	938	500/900	938	500/900	625	600/900	150	225/900	4214	2×1500	750	4200	1.0	6600	25	500	20.71	10.44	6.36	4.15	3.48	4.39	114/205	226/406	371/667	568/1022	818/1819
2	Wheeling Steel Corp. Yorkville	1934	42	18	49	20	13'-0"	10'-6"	800	600/800	800	600/800	800	600/800	800	600/800	800	600/800	150	300/900	4150	2×1250	2×1000	3600	.80	4000	60	720	16.18	10.44	6.36	4.15	3.48	4.85	174/233	271/361	444/592	681/910	812/1060
3	Wheeling Steel Corp. Yorkville	1937	42	18	49	20½	13'-0"	10'-6"	500	450/600	1000	600/800	1000	600/800	1000	600/800	1250	600/800	150	300/1200	4900	2×1750	600	5000	.80	4000	60	514	10.44	8.81	5.06	3.68	3.12	4.85	203/271	321/428	558/745	770/1085	908/1210
4	Weirton Steel Co. Weirton	1934 Rebuilt 1936	38	19	45	16½	15'-0"		350	450/900	900	470/900	900	420/900	1500	420/900	—	—	150	600/1400	3800	2250	350	3200	.80	6600	60	514	17.35	10.4	7.13	4.43	—	5.68	129/258	201/431	293/629	471/1010	—
5	Weirton Steel Co. Weirton	1936	42	19	45	16½	13'-0"		400	600/1200	1000	600/800	1000	600/800	1500	600/900	—	—	200	300/1200	4100	2×1750	600	5100	.80	6600	60	514	15.95	5.72	3.97	2.32	—	3.87	187/375	346/696	501/1002	644/1500	—
6	Crown Cork and Seal Co. Baltimore	1936	32	18	39	20			600	500/800	600	500/800	600	500/800	600	500/800	600	500/800	100	350/1400	3100	2×1000	250	2900	.80	2200	60	720	20.71	10.44	6.36	4.42	4.15	7.54	114/182	224/362	371/592	534/858	564/910
7	Carnegie-Illinois Steel Corp. Gary	1936	42	20	49	20	13'-0	10'-6"	500	450/800	1250	350/750	1250	350/750	1250	350/750	1250	350/750	250	300/1250	5750	2×2500	600	7050	1.0	6600	60	514	14.83	6.27	3.91	2.94	2.64	4.00	159/282	282/625	469/1004	628/1395	694/1488
8	Carnegie-Illinois Steel Corp. Gary	1937	42	20	49	20	13'-0	10'-6"	500	450/800	1250	350/750	1250	350/750	1250	350/750	1250	350/750	250	300/1250	5150	2×2500	600	7050	1.0	6600	60	514	14.83	6.27	3.91	2.94	2.64	4.00	159/282	282/625	469/1004	628/1395	694/1488
9	Bethlehem Steel Corp. Sparrow's Point	1935 Rebuilt 1939	42	18½	49½	16½	13'-0"	10'-6"	800	600/800	1500	600/900	1500	600/900	1500	600/900	1500	600/900	225	225/900	7025	2×1250 2×2500	600	—	.80 .80	6600	25	750 500	12.43	7.58	4.89	3.31	2.50	2.02	231/308	379/567	587/880	876/1305	1180/1765
10	Bethlehem Steel Corp. Sparrow's Point	1937	42	18½	49½	16½	13'-0	10'-6"	500	600/800	1000	600/800	1000	600/800	1000	600/800	1250	600/800	225	225/900	4975	3500	600	F.C.	.80	6600	60	380	11.00	6.92	4.15	2.93	2.49	2.02	261/348	414/552	624/832	930/1301	832/1536
11	Republic Steel Corp. Niles	1937	42	19	53	16½	13'-0"		500	600/1200	1000	600/800	1000	600/800	1500	600/900	—	—	250	300/1200	4250	2×1750	600	5050	.80	2200	60	514	14.10	5.26	3.69	2.08	—	3.61	212/424	376/736	599/1078	717/1434	—
12	Tennessee Coal Iron & RR Co. Fairfield	1938	42	20	58	20	13'-0"	10'-6"	500	480/1050	1250	350/750	1250	350/750	1250	350/750	1250	350/750	250	300/1350	5750	2×2500	600	7050	1.0	6600	60	514	14.83	6.27	3.91	2.94	2.64	4.00	159/371	292/660	469/1069	623/1410	695/1565
13	Tennessee Coal Iron & RR Co. Fairfield	1938	42	20	53	20	13'-0"	10'-6"	500	480/1050	1250	350/750	1250	350/750	1250	350/750	1250	350/750	250	300/1350	5750	2×2500	600	7050	1.0	6600	60	514	14.83	6.27	3.91	2.94	2.64	4.00	159/371	292/660	469/1060	623/1410	695/1565
14	Carnegie-Illinois Steel Corp. Irvin	1938	42	20½	53	20	13'-0"	10'-6"	600	450/1200	1500	500/750	1500	500/750	1500	500/750	1500	500/750	300	300/1350	6900	2×2500	600	7050	.95	6600	60	514	14.83	6.27	3.91	2.94	2.64	4.00	163/360	300/675	480/1082	638/1440	712/1605
15	Youngstown Sheet & Tube Co. Indiana Harbor	1939	54	18	49	20	13'-0"	9'-3"	1500	500/600	1750	500/600	1750	500/600	1750	500/600	1750	500/600	400	300/1200	8900	2×2500	600	8500	1.0	11000	60	514	5.87	3.94	2.63	1.89	Direct	2.85	241/482	359/718	539/1078	750/1500	827/2065
16	Weirton Steel Co. Weirton	1940	35	19	45	16½	11'-8"		700	350/875	1750	500/600	1750	375/900	2500	250/500	—	—	300	125/600	7000	2×3000	720	5400	.90	6600	60	360	7.13	2.82	Direct	Direct	—	Direct	246/615	534/1448	875/1789	1789/2500	—

TABLE II

LARGE TANDEM COLD REDUCTION STRIP MILLS

Nº	Company and Location	Year Installed	Roll Face	Diameter of: Work Rolls	Diameter of: Back Rolls	Diameter of: Reel Drum	Spacing: Between Stands	Spacing: Last Stand & Reel	Motors: Stand #1 HP	Stand #1 RPM	Stand #2 HP	Stand #2 RPM	Stand #3 HP	Stand #3 RPM	Stand #4 HP	Stand #4 RPM	Reel HP	Reel RPM	Total HP	Main M-G Set: Generators Kw	Generators Volts	Motor HP	Motor P.F.	Motor Volts	Motor Cycles	Motor RPM	Gear Ratio: Stand #1	Stand #2	Stand #3	Stand #4	Winding Reel	Roll F.P.M.: Stand #1	Stand #2	Stand #3	Stand #4
1	Inland Steel Co. Indiana Harbor	1932 Rebuilt 37	72	20	44	30	16'-0	10'-4"	1250	400/800	1250	400/800	1250	400/800	—	—	150	225/900	3900	3×1250	600	3×1750	1.0	6600	25	750	17.5	10.1	7.1	—	8.82	120/240	207/414	295/590	—
2	Youngstown Sheet & Tube Co. Youngstown	1935	75	20½	49	24½	16'-0"	10'-4"	1250	500/600	1250	500/600	1250	500/600	—	—	225	225/900	3975	2×2000	600	5600	.80	6600	60	450	10.44	6.36	5.06	—	9.18	154/308	283/506	318/636	—
3	Ford Motor Co. Detroit	1935	66	19	49	30	18'-0	10'-0	1500	350/700	1500	350/700	1500	350/700	—	—	400	300/1050	4900	2×1650	2×2750	2×2100		13,200	60	514	8.12	5.88	4.68	—	10.55	214/429	296/593	373/746	—
4	Bethlehem Steel Corp. Lackawanna	1936	75	20	49	24½	16'-0"	10'-6"	1250	300/600	1250	300/600	1250	300/600	—	—	225	225/900	3975	3000	600	8500/2	.90	6600	25	375	10.44	6.36	5.06	—	9.18	150/300	246/492	309/619	—
5	Great Lakes Steel Corp. Ecorse	1936	93	20½	53	28	16'-0"	10'-6"	1250	300/600	1250	300/600	1250	300/600	—	—	225	225/900	3975	3000	600	8500/2	.90	6600	60	360	10.44	6.36	5.06	—	10.00	154/308	253/506	318/636	—
6	American Rolling Mill Co. Middletown	1936	80	19	49	30	20'-0"	12'-0"	1500	300/600	1500	300/600	1500	300/600	—	—	600	300/1050	5100	2×2000	600	5600	.90	6600	60	514	7.40	5.95	4.95	—	12.0	201/402	276/552	300/600	—
7	Carnegie-Illinois Steel Corp. Gary	1936	84	20½	56	30	16'-0	14'-6"	1500	200/400	2500	225/450	2500	225/450	—	—	350	200/700	6850	2×3000	600	8400	1.0	6600	60	360	8.38	5.48	4.43	—	7.96	128/256	217/435	271/542	—
8	Jones & Laughlin Steel Corp. Pittsburgh	1937	93	20½	53	28	16'-0"	10'-6"	1500	300/600	1500	300/600	1500	300/600	—	—	225	225/900	4725	2×1750	600	4800	1.0	6600	25	500	8.80	5.43	4.15	—	8.16	183/366	296/592	388/776	—
9	Republic Steel Corp. Cleveland	1937	98	20½	53	30	16'-0"	12'-9"	1500	300/600	2500	225/450	2500	225/450	—	—	600	250/875	7100	2×3000	600	8500	.90	11,000	60	360	6.79	3.67	3.02	—	8.16	237/474	328/656	400/800	—
10	Carnegie-Illinois Steel Corp. Irvin	1938	84	20½	56	30	16'-0"	14'-6"	2500	225/450	3500	150/300	2500	225/450	—	—	800	250/750	9300	2×3500	600	10,150	.95	6600	60	360	4.97	2.38	2.65	—	6.20	276/553	338/677	455/910	—
11	Otis Steel Co. Cleveland	1932 Rebuilt 38	77	21	52	30			1250	250/625	1500	200/500	1500	200/500	—	—	250	300/1350	4500	2×1250	600	3570	.80	11,000	60	720	10.6	6.96	4.80	—	15.25	130/318	159/396	256/640	—
1	Inland Steel Co. Indiana Harbor	1932 Rebuilt 37	54	20	44	24⅜	16'-0"	10'-4"	500	400/800	750	400/800	1250	400/800	800	400/800	150	225/900	3450	2×1250	600	3600	1.0	6600	25	750	17.5	10.1	7.1	5.4	6.86	120/240	207/414	295/590	389/775
2	Bethlehem Steel Corp. Lackawanna	1936	54	20	49	24½	16'-0"	10'-6"	1250	300/600	1250	300/600	1250	300/600	—	—	225	225/900	3975	3000	600	8500/2	.90	6600	25	375	6.36	4.57	3.36	—	6.24	247/494	343/686	468/937	—
3	Great Lakes Steel Corp. Ecorse	1936	54	20	53	28	16'-0"	10'-6"	1250	300/600	1250	300/600	1250	300/600	—	—	225	225/900	3975	3000	600	8500/2	.90	6600	60	360	10.44	6.36	5.06	—	10.00	150/301	247/494	310/621	—
4	Jones & Laughlin Steel Corp. Pittsburgh	1937	54	20½	53	20	16'-0"	10'-6"	1500	300/750	1500	300/750	1500	300/750	1500	300/750	225	225/900	6225	2×1750	600	4800	1.0	6600	25	500	8.80	5.43	3.48	2.82	3.74	183/487	297/742	463/1186	572/1490
5	Youngstown Sheet & Tube Co. Youngstown	1937	54	20	49	20	16'-0"	10'-4"	1250	300/600	1250	300/600	1250	300/600	1250	300/600	225	225/900	5225	2×1800	600	4500	.80	6600	60	514	6.36	4.42	3.12	2.49	4.09	247/494	355/710	504/1008	632/1864
6	Wheeling Steel Corp. Steubenville	1940	55	20½	53	24	20'-0"	10'-4"	1200	200/400	2000	150/300	2000	150/300	2000	150/300	500	250/875	7700	2×2500	600	9800	.90	6600	60	360	4.17	1.78	1.22	Direct	3.365	257/515	453/906	660/1320	807/1614

TABLE III

42 in. Five-Stand Tandem Cold Reduction Strip Mill

Test-Rolling 26⅞ in. x .074 in. Mild Steel Strip to 26⅞ in. x .0094 in. Strip for Tinplate

		1		2		3		4		5		Reel	Total
1. Pass number													
2. Motor amperes		280		1140		1005		1060		1080		85	4650
3. Motor volts		665		665		665		665		665		730	
4. Motor kw		186		757		669		705		719		62	3098
5. Motor hp		230		955		840		885		905		75	3890
6. Motor rpm		658		585		562		625		710			
7. Gear ratio		14.83		6.27		3.91		2.94		2.64			
8. Roll diameter		20.10		20.40		20.45		20.30		20.25			
9. Roll ft. per min		235		499		765		1130		1425			
10. Strip thickness, in	.074		.057		.0269		.0175		.0118		.0094		
11. Strip cross section, sq. in.	1.99		1.53		.722		.470		.317		.253		
12. Per cent reduction		23.0		52.8		35.0		32.6		20.3			87.3
13. Total elongation			1.30		2.75		4.23		6.27		7.87		
14. Estimated tension													
a. Per sq. in			15,000		20,000		25,000		25,000		6,875		
b. Total			23,000		14,440		11,730		7,920		1,740		
15. Tension hp			165		220		270		270		75		
16. Net rolling hp		395		1010		890		885		710			3890
17. Net tons per hr													36.4
18. Hp. hours per net ton													
a. Per pass		10.9		27.7		24.5		24.3		19.5			106.9
b. Total			10.9		38.6		63.1		87.4		106.9		

could be obtained from the usual indicating meters, it being necessary only to get simultaneous readings on all of the meters while the mill is operating under stable conditions at the normal rolling speed.

In addition to this electrical power data, it is necessary to also secure mill and rolling data, including the diameter of the working rolls in each mill stand, the gear ratio for each stand, the width and thickness of the hot strip entering the mill, the width and thickness of the finished cold reduced strip, and, if possible, the thickness after each pass.

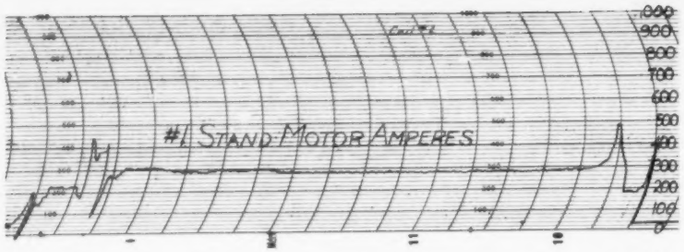
This power and mill data may now be set down in tabulated form, as shown in Table III, and reduced by calculation to a unit basis so that an energy consumption curve can be plotted. Referring to Table III, the armature amperes and applied voltage for each of the mill and reel motors are listed in lines 2 and 3, and assuming the proper motor armature efficiency (usually about 94 per cent for the mill motors, and slightly lower for the reel motor) the hp. output of each motor is calculated and listed in line 5. The speed of each of the mill motors, gear ratios, and working roll diameters, are listed in lines 6, 7 and 8, and from this data the peripheral speed of the working rolls in each stand is calculated and listed in line 9.

The strip thickness after each pass may be obtained by actual micrometer measurement, however in the usual case this is quite difficult, and the values of strip thickness between stands are usually arrived at by calculation. In a continuous mill arrangement, the same volume of material must be delivered from each stand, so that the thickness after each stand may be arrived at by dividing the speed of that stand into the product of the finished thickness and the speed of the last stand. By this means the strip thickness and cross section area after each pass are calculated and listed in lines 10 and 11, and the per cent reduction in each pass, and the

TABLE IV

Power Calculation—Rolling 32 in. Wide by .078 in. Thick Mild Steel Strip to 32 in. Wide by .0105 in. Thick—5 Passes—1800 F.P.M.

		1		2		3		4		5		Reel	Total
1. Pass number													
2. Strip thickness, in	.078		.055		.030		.020		.0135		.0105		
3. Strip cross section, sq. in.	2.50		1.76		.96		.64		.432		.336		
4. Per cent reduction		29.5		45.5		33.3		32.5		22.2			86.5
5. Total elongation	1.00		1.42		2.60		3.90		5.77		7.42		
6. Strip ft. per min	242		344		630		945		1400		1800		
7. Net tons per hour													60.8
8. Hp. hours per net ton													
a. Total (from curve)	0		14.5		37.7		57.3		81.7		101.0		
b. Per pass		14.5		23.2		19.6		24.4		19.3			101.0
9. Net rolling hp		885		1410		1190		1485		1170			6140
10. Estimated strip tension													
a. Per sq. in			20,000		25,000		30,000		30,000		10,000		
b. Total			35,200		24,000		19,200		12,950		3,360		
11. Tension hp			365		460		550		550		185		
12. Net motor hp		520		1315		1100		1485		1535		185	6140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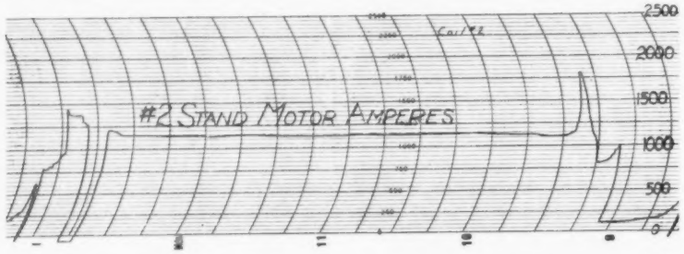
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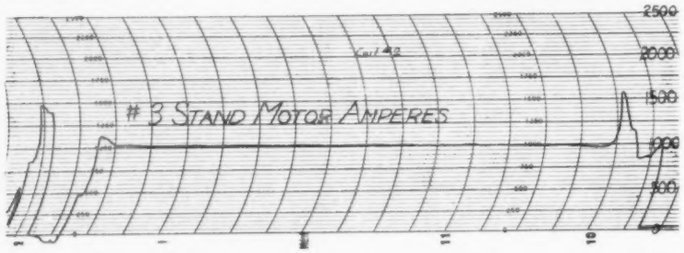
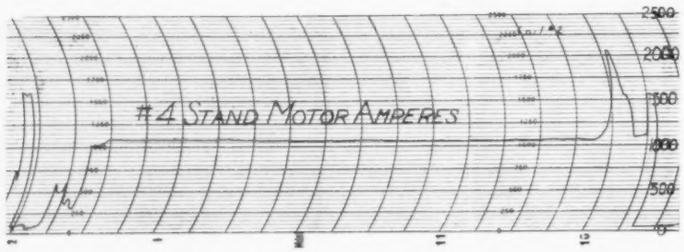
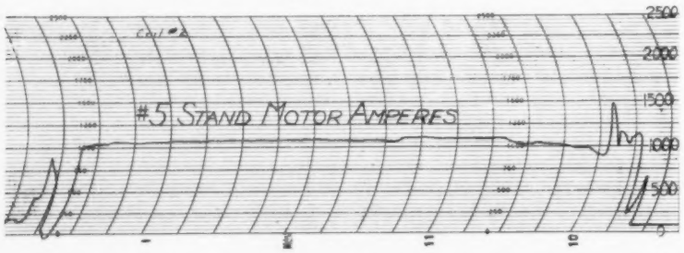

3 Stand Motor Amperes


#4 Stand Motor Amperes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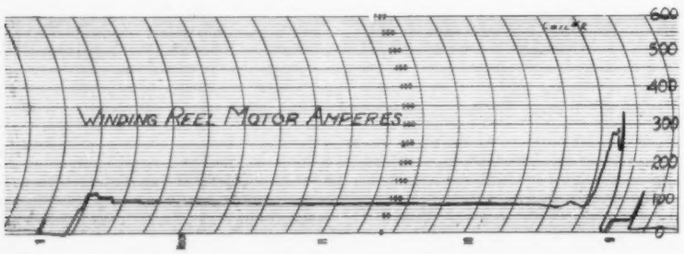
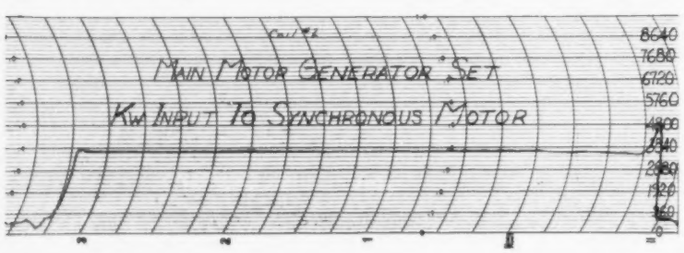
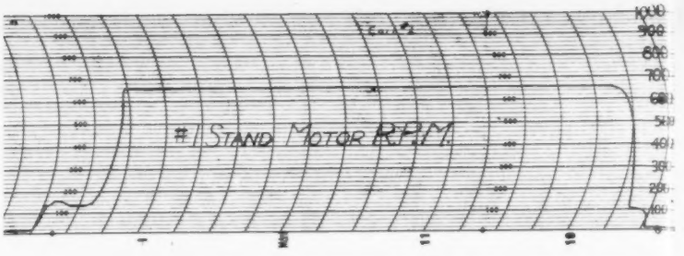

Winding Reel Motor Amperes


Main Motor Generator Set
Kw Input To Synchronous Motor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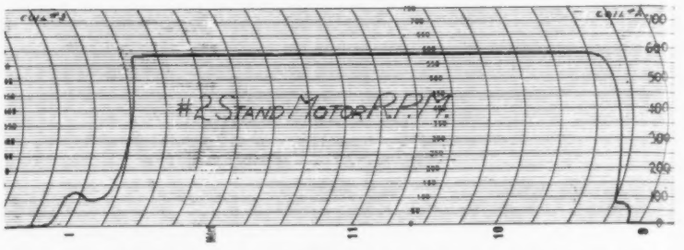
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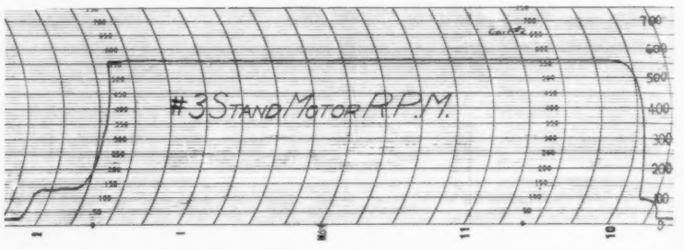
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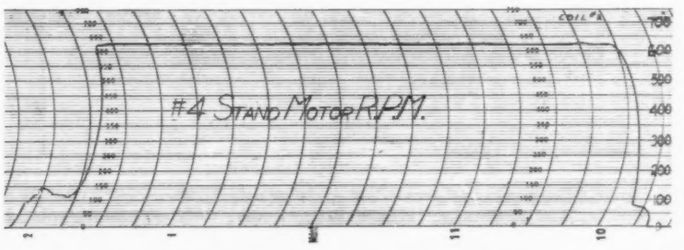
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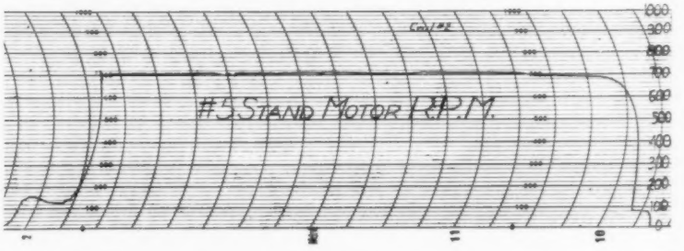
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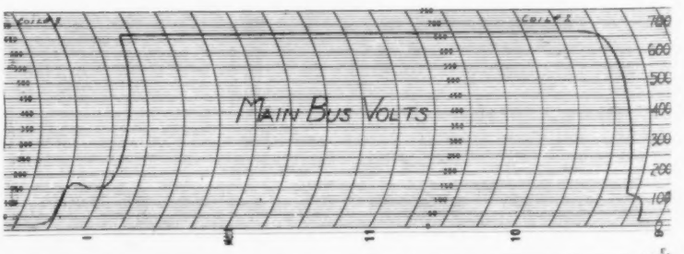

Main Bus Volts

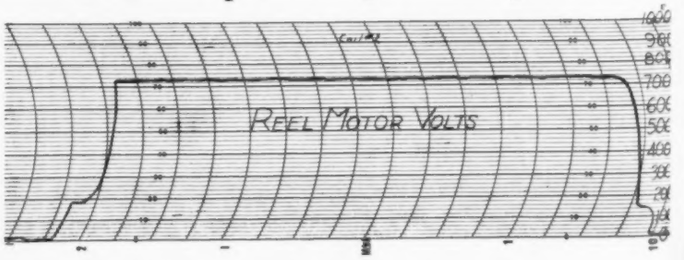
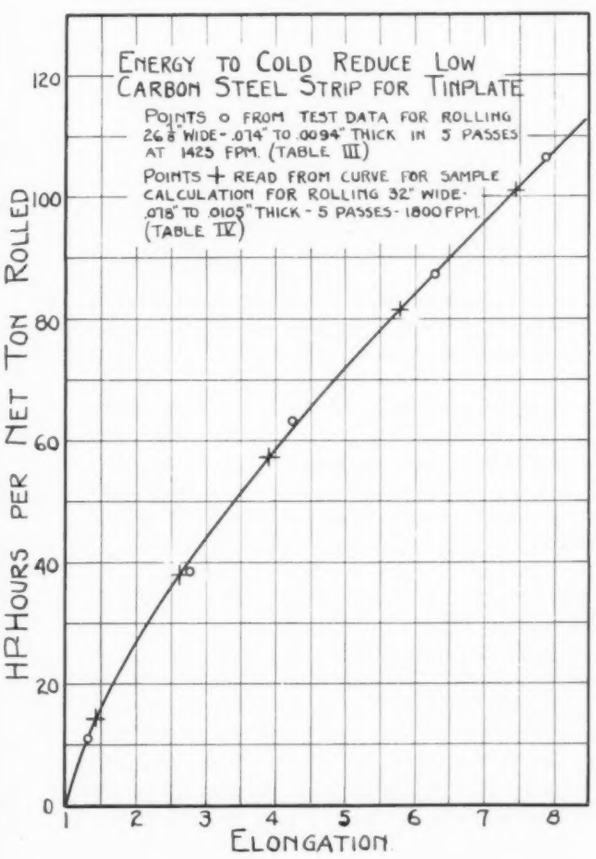

Reel Motor Volts

FIGURE 1—*(opposite page)* Graphic meter charts taken from 5-stand tandem mill rolling 26⅞ in. material from .074 in. to .0094 in., at 1425 ft. per min. delivery speed.

total elongation at the end of each pass, are calculated and listed in lines 12 and 13.

It will be noted that the hp. outputs of the mill and reel motors were calculated and listed in line 5. These values of motor hp. however do not represent the work done in reducing the steel in the individual passes, because of the interchange of power by the tension in the strip between stands, and between the last stand and the reel. Some few mills are equipped with tensiometers by which the strip tension between stands may be measured, however this particular mill was not so equipped, and the values of strip tension were estimated, as listed in lines 14-a and 14-b. From the values of total tension, line 14-b, and strip speed, line 9, the power interchange between stands due to the strip tension is calculated, and listed in line 15.

FIGURE 2


ENERGY TO COLD REDUCE LOW CARBON STEEL STRIP FOR TINPLATE
POINTS o FROM TEST DATA FOR ROLLING 26⅞" WIDE - .074" TO .0094" THICK IN 5 PASSES AT 1425 FPM. (TABLE III)
POINTS + READ FROM CURVE FOR SAMPLE CALCULATION FOR ROLLING 32" WIDE - .078" TO .0105" THICK - 5 PASSES - 1800 FPM. (TABLE IV)
HP HOURS PER NET TON ROLLED
0
20
40
60
80
100
120
1
2
3
4
5
6
7
8
ELONGATION

The net power used in reducing the strip in each stand now may be arrived at. For instance, note that the No. 3 stand motor output is 840 hp. However due to the strip tension stand No. 3 is pulling 220 hp. on the preceding stands, and is being pulled 270 hp. by the following stands, so that the net rolling power for stand No. 3 is 840—220+270=890 hp.

The mill output in net tons per hour is now calculated as .253 sq. in. cross section of the finished strip times 12 in. per ft. times 1425 ft. per min. delivery speed times .28 lb. per cu. in. times 60 min. in an hour all divided by 2000 lb. in a net ton, or 36.4 net tons per hour. It will be noted that the constant factors are

$$\frac{12 \times .28 \times 60}{2000} = .1055,$$

so that the net tons per hour output is almost exactly one-tenth of the product of the cross section in sq. in. and the speed in ft. per min.

Now having determined the net hp. used in reducing the steel in each pass, and the output in tons per hour, the test data may be reduced to the unit energy basis of hp. hours per net ton rolled by dividing the rolling hp. by the mill output. Line 18-a shows this unit figure for each of the five passes, and line 18-b is the accumulative total of the energy requirement for all of the preceding passes.

This data may now be plotted in curve form, using the total elongation to the end of each pass, line 13, as the abscissae, and the cumulative total of hp. hours per net ton, line 18-b, as the ordinates, making the energy consumption curve as shown in Figure 2.

Data from this energy consumption curve now may be used to calculate the probable motor loads for some other schedule of reductions, or other rolling speed, going through the process in reverse order from that used in working out the test data. Such a power calculation need not be described in detail, but will be obvious from the above and from analysis of the sample power calculation shown in Table IV.

ENERGY CONSUMPTION CURVES

The preceding section of the paper has described in detail the method of working up a typical set of test data from a tandem cold reduction mill, and also the use of data from the resulting energy consumption curve in a sample power calculation to determine the expected motor loads which will be imposed by another rolling schedule. It is obvious that different energy consumption curves will be obtained for rolling various grades of steel, rolling from various widths and gauges of hot strip, variations in reductions, etc., hence data from the energy consumption curves must be used only under approximately the same conditions as were present when the test data was obtained. Data from many hundreds of tests on more than twenty different tandem and reversible type mills have been analyzed and plotted in curve form, and in the following we present some of these test curves, with accompanying comments

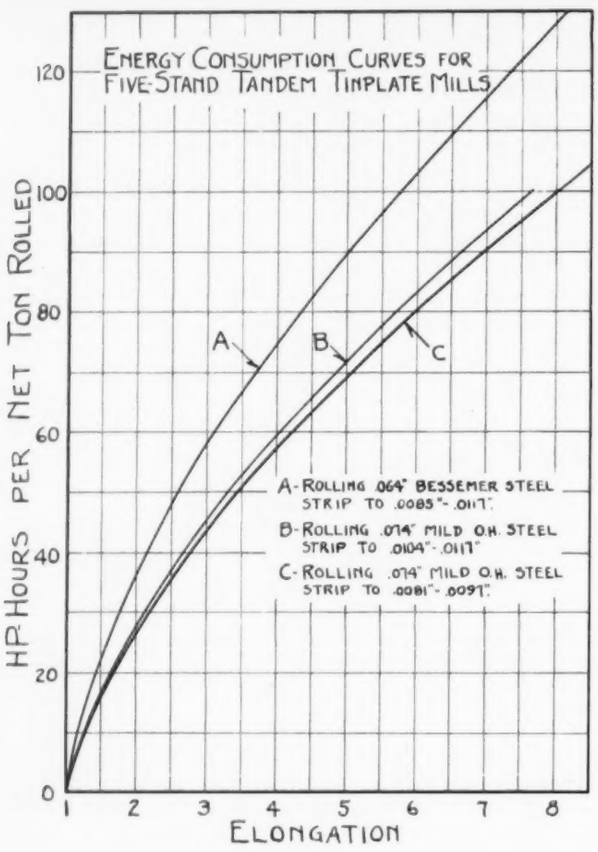

ENERGY CONSUMPTION CURVES FOR FIVE-STAND TANDEM TINPLATE MILLS
HP HOURS PER NET TON ROLLED
ELONGATION
A
B
C
A-ROLLING .064" BESSEMER STEEL STRIP TO .0085"-.0117"
B-ROLLING .074" MILD O.H. STEEL STRIP TO .0104"-.0117"
C-ROLLING .074" MILD O.H. STEEL STRIP TO .0081"-.0097"

FIGURE 3

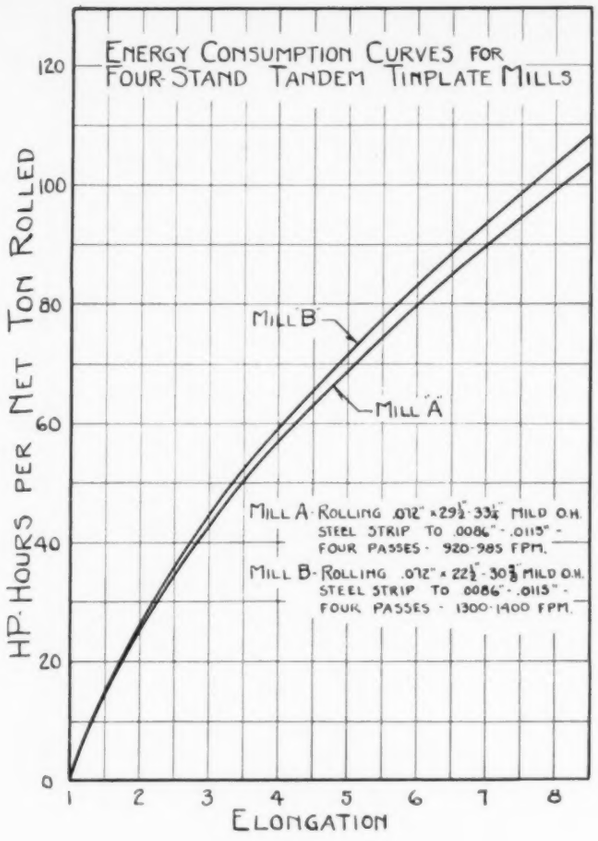

ENERGY CONSUMPTION CURVES FOR FOUR-STAND TANDEM TINPLATE MILLS
HP HOURS PER NET TON ROLLED
ELONGATION
MILL B
MILL A
MILL A-ROLLING .072" x 29½"-33¼" MILD O.H. STEEL STRIP TO .0086"-.0115" - FOUR PASSES - 920-985 FPM.
MILL B-ROLLING .072" x 22½"-30⅜" MILD O.H. STEEL STRIP TO .0086"-.0115" - FOUR PASSES - 1300-1400 FPM.

FIGURE 4

as to the conditions under which they were obtained, to enable their use in making power calculations.

Tinplate: The curves on Figure 3 show the results of about twenty tests made on two similar five-stand tandem cold reduction tinplate mills. The upper curve "A" is the average of several tests for the rolling of Bessemer steel strip, .064 in. thick and from 27⅞ in. to 31¼ in. wide, to .0085 in. to .0117 in. thick strip for tinplate, at 1320 to 1410 ft. per min. final delivery speed. The reduction when finishing to the .0085 in. thick strip were about 19, 41, 42, 42, and 23 per cent, respectively, in the five passes. The two lower curves are each the average of several tests for the rolling of low carbon open hearth steel strip, .074 in. thick and from 25½ in. to 32½ in. wide. The lower of the two curves "C" is for rolling to extremely light finished gauges, .0081 in. to .0097 in. thick, and the slightly higher curve "B" is for rolling to heavier finished gauges, .0104 in. to .0117 in. thick. A typical schedule for reducing .074 in. thick strip to .0104 in. thick, 29⅜ in. wide, at 1400 ft. per min. delivery speed, used reductions of about 22, 42, 38, 34 and 23 per cent respectively, for the five passes.

The curves on Figure 4 show the results of continuous tests over a period of several days time on two four-stand tandem cold reduction mills, normally rolling .072 in. thick low carbon open hearth steel strip to various light gauges for tinplate. The upper curve "B" is the average for about 35 orders rolled on one mill, rolling .072 in. thick and from 22½ in. to 30⅝ in. wide, to .0086 in., .0097 in., .0102 in., .0108 in., and .0115 in. thick strip for tinplate, at 1300–1400 ft. per min. delivery speed. Usual reductions were about 30 per cent in stand No. 1, 44–48 per cent in stand No. 2, 38–44 per cent in stand No. 3, and 34–40 per cent in stand No. 4. The lower curve "A" is the average of a large number of orders rolled on another mill, producing practically the same range of widths and finished gauges, but rolling at slower delivery speed of about 920–985 ft. per min. Usual reductions were about 34 per cent in stand No. 1, 40–45 per cent in stand No. 2, 35–40 per cent in stand No. 3, and 35–40 per cent in stand No. 4. It will be noted that the curves from these four-stand tandem tinplate mills correspond quite closely with the lower curves "B" and "C" of Figure 3, for similar rolling on five-stand tandem mills, indicating that the net energy consumption for the same elongation is practically the same for rolling in either a four-stand or five-stand mill.

The curves shown on Figures 3 and 4 were the result of tests of narrow (38 in. to 42 in.) four-stand and five-stand tandem mills, geared for relatively high delivery

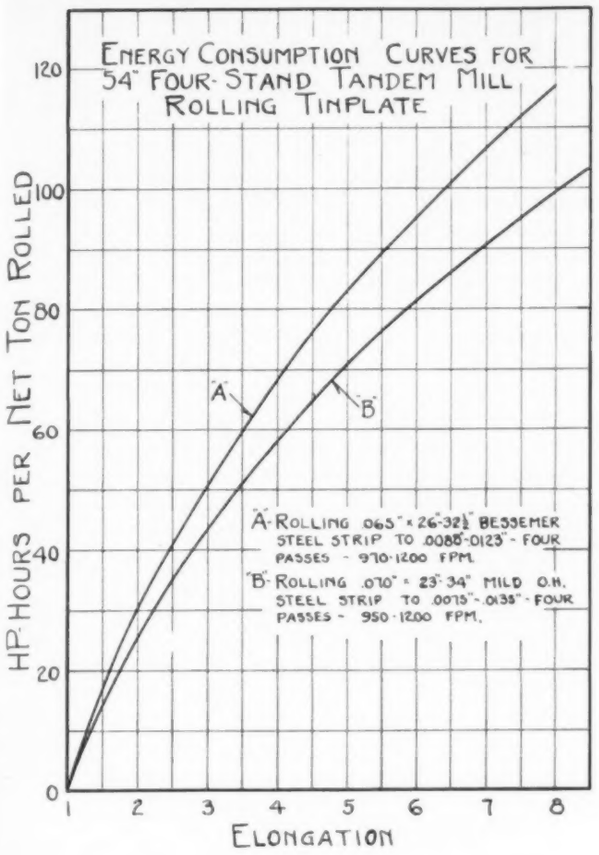

ENERGY CONSUMPTION CURVES FOR 54" FOUR-STAND TANDEM MILL ROLLING TINPLATE
HP-HOURS PER NET TON ROLLED
ELONGATION
"A"
"B"
"A" ROLLING .065" × 26"-32½" BESSEMER STEEL STRIP TO .0088"-.0123" - FOUR PASSES - 970-1200 FPM.
"B" ROLLING .070" × 23"-34" MILD O.H. STEEL STRIP TO .0075"-.0135" - FOUR PASSES - 950-1200 FPM.

FIGURE 5

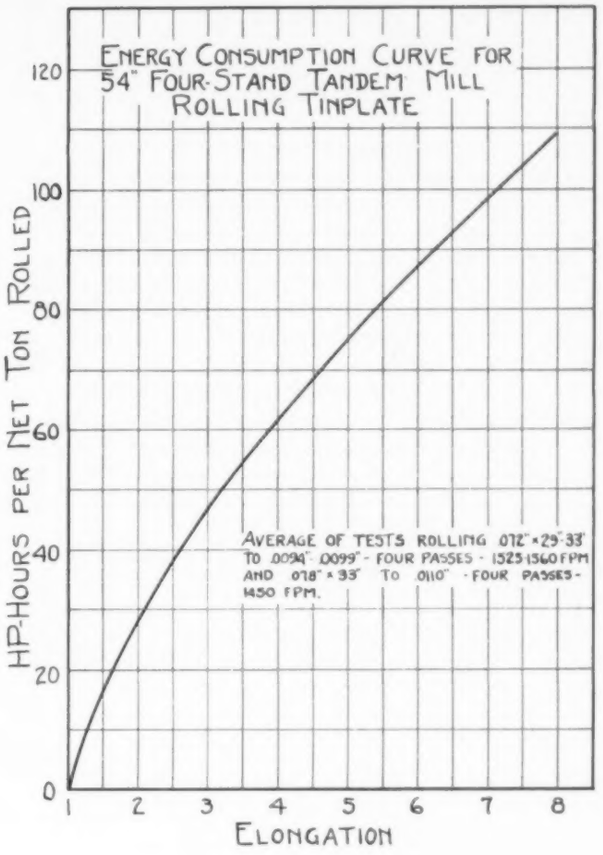

ENERGY CONSUMPTION CURVE FOR 54" FOUR-STAND TANDEM MILL ROLLING TINPLATE
HP-HOURS PER NET TON ROLLED
ELONGATION
AVERAGE OF TESTS ROLLING .072" × 29"-33" TO .0094"-.0099" - FOUR PASSES - 1525-1560 FPM AND .078" × 33" TO .0110" - FOUR PASSES - 1450 FPM.

FIGURE 6

speeds, and primarily intended for the production of light gauge strip for tinplate. The curves on Figures 5 and 6 are from two different 54 in. wide four-stand tandem mills, which were installed for the normal production of medium to heavy sheet gauge strip, but which due to business conditions, have been producing considerable tonnages of light gauge tinplate strip.

The upper curve "A" on Figure 5 is the average of about twenty tests for the rolling of Bessemer steel strip, .065 in. thick and from 26 in. to 32½ in. wide, to .0088 in., .0091 in., .0100 in., .0105 in., .0118 in. and .0123 in. thick, in four passes, at 970–1200 ft. per min. delivery speed. The lower curve "B" is the average of several orders rolled on the same mill for the rolling of low carbon open hearth steel strip, .070 in. thick and from 23 in. to 34 in. wide, to .0085 in., .0077 in., .0083 in., .0088 in., .0094 in., .0100 in., .0105 in., .0113 in., .0115 in., .0120 in. and .0135 in. thick, in four passes, and at 950–1200 ft. per min. delivery speed. Curve "A" for rolling Bessemer steel strip, is slightly lower than curve 3-A for rolling Bessemer steel strip on the five-stand mill, while curve "B," for rolling mild open hearth steel strip, checks very closely with curves 3-B, 3-C, 4-A and 4-B, for similar rolling of low carbon steel strip on the other mills. The gear ratios on stands No. 3 and 4 and the reel of this 54 in. mill have been changed since these tests were made to increase the maximum delivery speed to about 1450 ft. per min., and to make the individual stand speeds more suitable for the reductions normally used for tinplate rolling.

The curve on Figure 4 was plotted from the average of several coils on each of five different orders, rolling .072 in. and .078 in. thick, 29 in. to 33 in. wide, low carbon steel strip, to .0094 in., .0099 in. and .0110 in. thick strip for tinplate, on a 54 in. four-stand tandem mill, at 1450 to 1560 ft. per min. delivery speed. Reductions were about 30–32 per cent in stand No. 1, 44–48 per cent in stand No. 2, 42–45 per cent in stand No. 3, and 27–35 per cent in stand No. 4.

The curve on Figure 7 shows the energy consumption for a 42 in. single stand reversible type cold reduction tinplate mill, rolling 29½ in. wide by .082 in. low carbon open hearth steel strip to 29½ in. wide by .0112 in. thick, in five passes. The first pass was rolled at about 600 ft. per min. gradually increasing to about 840 ft. per min. maximum during the last two passes. Reductions were about 46, 43, 36, 21 and 12 per cent, respectively, for the five passes.

Galvanized Roofing: Strip used in the manufacture of galvanized roofing sheets is usually quite narrow, 28 in.

to 36 in. wide, and intermediate in gauge between tinplate and automobile body and fender sheets, and hence in some plants may be rolled on mills normally operating on tinplate, and in other plants may be produced by the larger mills primarily intended to roll wider sheet gauge material.

In Figure 8, the upper curve "A" is the average of several tests on a large three-stand tandem cold reduction mill rolling 25 in. to 36¾ in. wide, .065 in. to .078 in. thick, low carbon steel strip, to finished thickness ranging from .016 in. to .026 in., at 610–740 ft. per min. delivery speed. The lower curve "B" is the result of similar tests on a 54 in. four-stand tandem mill in the same plant, rolling 22 in. to 34⅜ in. wide, .065 in., .070 in., .074 in., and .083 in. thick, hot strip, to finished strip .0135 in. to .020 in. thick, at 830–1200 ft. per min. The higher energy consumption for rolling on the larger mill is apparently due to the greater effect of the higher mill friction losses, thus indicating the economy of rolling on the smaller mill which is particularly adapted for this class of work.

The curve on Figure 9 shows the average results from the rolling of several coils of 29 7/16 in. wide by .072 in. thick hot strip, to .0145 in. thick strip for galvanized roofing sheets, in a four-stand tandem tinplate mill, at 1142 ft. per min. delivery speed. Reductions were approximately 24, 40, 36, and 31 per cent, respectively, in the four passes.

The curve on Figure 10 covers the operation of a 54 in. three-stand tandem mill, and is the average result for rolling 36¾ in. x .074 in. to .024 in. at 510–590 ft. per min., 36¾ in. x .078 in. to .017 in. at 485 ft. per min., and 36¾ in. x .069 in. to .017 in. at 500 ft. per min.

It will be noted from each of the curves 8-B, 9, and 10, for rolling .0135–.026 in. thick strip for galvanized roofing sheets, the energy consumption for a given elongation is consistently higher than for the rolling of tinplate strip from approximately the same hot strip. This same tendency toward slightly higher unit energy consumption when finishing to heavier gauges was noted in the comparison of curves 3-B and 3-C.

Sheet Gauge Rolling: Figure 11 shows the average curve calculated from observations made while rolling about forty different orders on a 93 in. three-stand tandem cold reduction mill. The material rolled ranged from 35⅝ in. to 79⅞ in. wide. About half of the orders were rolled from .093 in. thick hot strip, finishing to .0345–.0389 in. thick, and the remaining orders were rolled from .105 in. thick hot strip, finishing to .0359–.0478 in. thick. The data from the two different entering gauges were analyzed separately, to determine any difference in the energy requirements, however it was

FIGURE 7

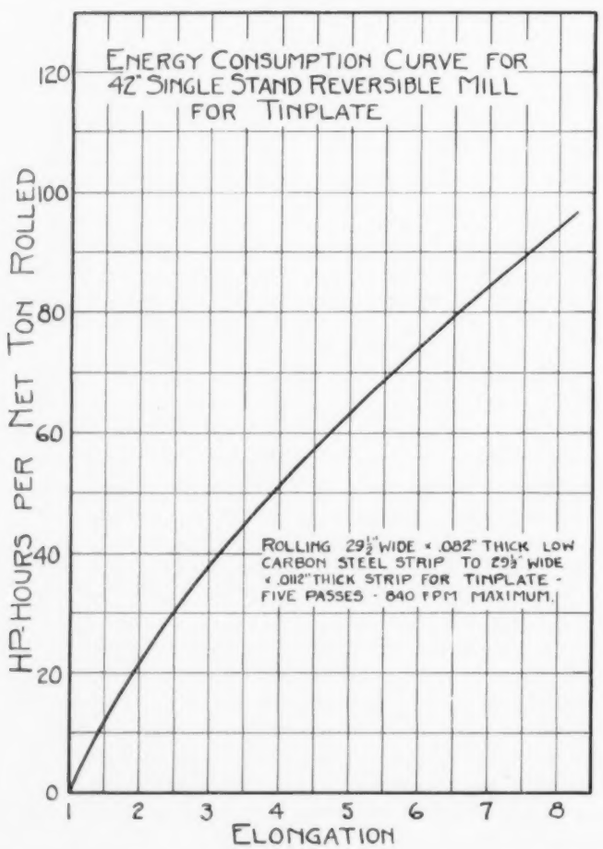
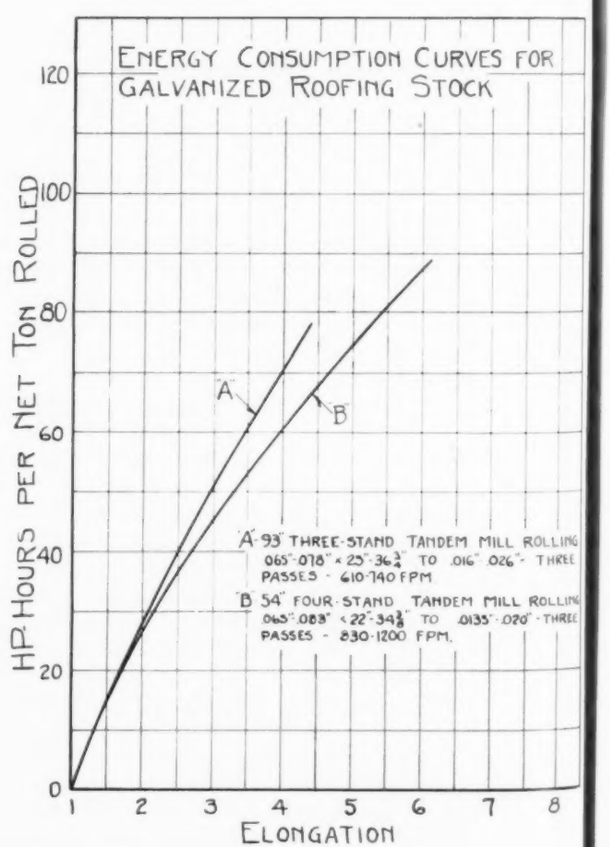


FIGURE 8



found that the average curves were almost coincident, and the curve on Figure 11 therefore represents the average energy requirement by this particular mill for rolling from either .093 in. or .105 in. thick hot strip.

Figure 12 is the average curve calculated from data obtained from two different 75 in. three-stand tandem mills, rolling from hot strip ranging from 34¾ in. to 74 in. wide, .090 in., .093 in., .100 in., and .105 in. thick, and finishing to .035–.042 in. thick. Again there was only slight difference in energy requirement which could be ascribed to the difference in thickness of the hot strip entering the cold reduction mill, however the energy for rolling the narrower width strip was quite consistently higher than the data for rolling the wider strip, probably reflecting the proportionately higher mill friction loads. This variation, however, was relatively small, amounting to not more than about 3 per cent above and below the average curve.

Figure 13 is the average curve from several coils on each of four different schedules rolled on an 80 in. three-stand tandem cold reduction mill. 67 in. wide x .100 in. thick strip was rolled to .036 in. thick, at 445 ft. per min. delivery speed, with reductions of approximately 45, 27 and 10 per cent; 66½ in. wide x .100 in. thick strip was rolled to .0375 in. thick at 380 ft. per min. delivery speed, with reductions of approximately 45, 26 and 8 per cent; and 40 in. and 57 in. wide x .125 in. thick strip were rolled to .047 in. thick, with reductions of about 44, 27 and 8 per cent. It will be noted that this curve is slightly higher than those on Figures 11 and 12, also it was observed that the energy for rolling the .125 in. thick strip was slightly higher than for rolling the .100 in. thick, indicating a slightly greater energy requirement for rolling from the thicker hot strip.

Figure 14 shows the results of tests of two 84 in. wide single stand reversible cold reduction mills. The upper curve "A" is for rolling 69 in. wide x .120 in. thick low carbon steel strip to .0365 in. thick, in five passes. Reductions were approximately 25 per cent in each of the first three passes, 17 per cent in pass 4, and 13 per cent in pass 5. The first two passes were run at about 230–260 ft. per min. and the last pass was run at about 385 ft. per min. The lower curve "B" is for rolling 37¼ in. wide x .095 in. thick low carbon steel strip to .031 in. thick, in three passes, with reductions of about 37, 37 and 18 per cent, respectively.

MILL OUTPUT AND GROSS ENERGY CONSUMPTION

The data shown on the preceding energy consumption curves is useful in determining individual motor loads, and total instantaneous loads. Estimates of expected

FIGURE 9

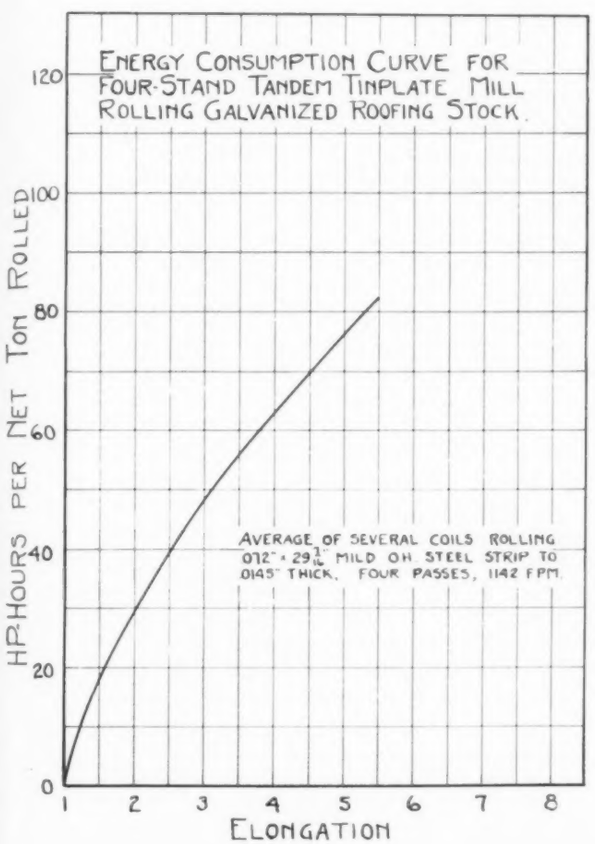
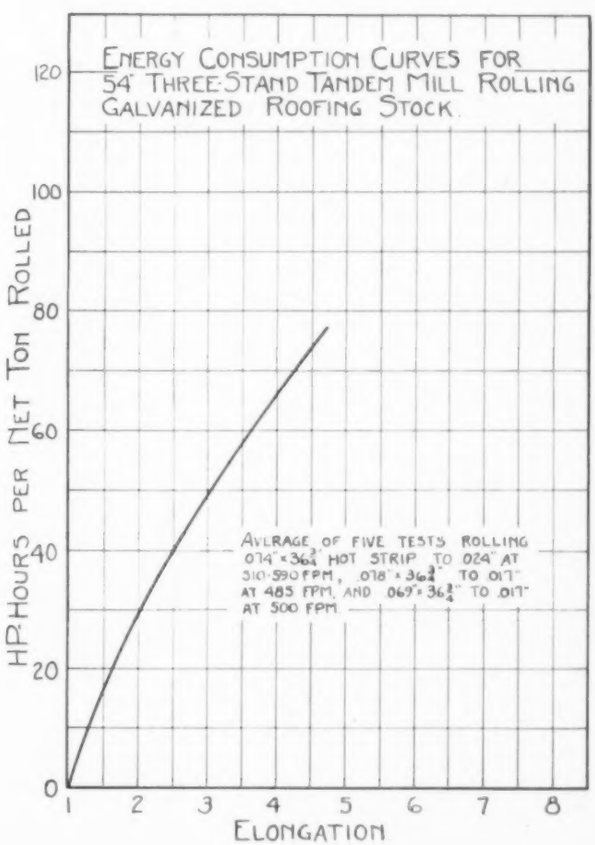


FIGURE 10



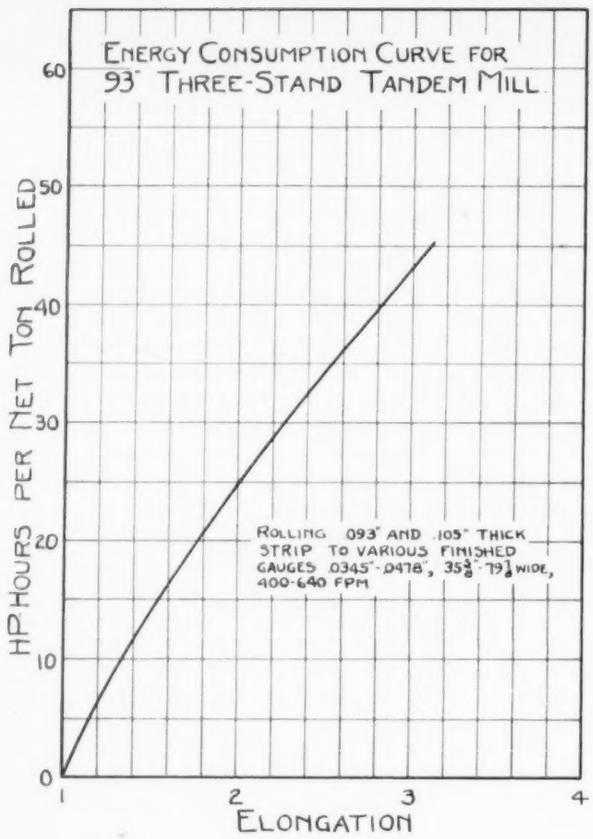


FIGURE 11

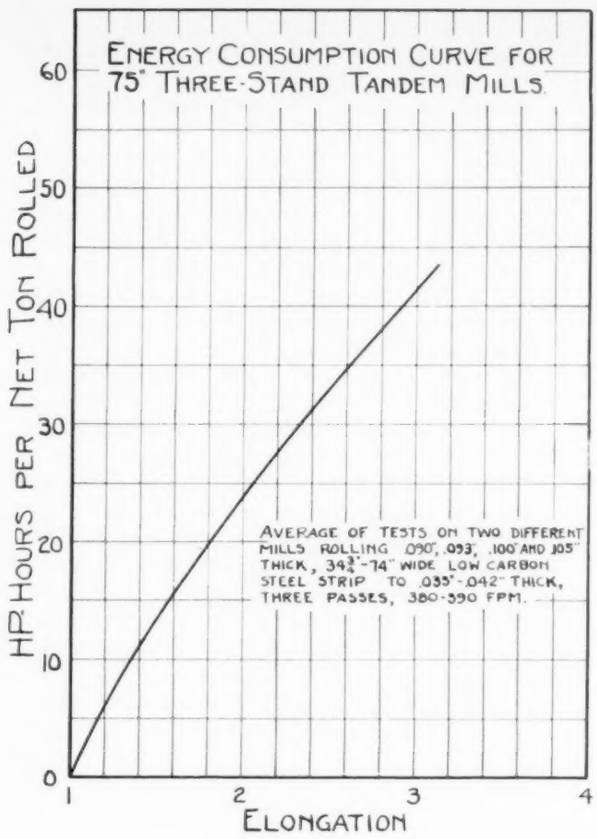


FIGURE 12

average power system demand and monthly kwh. consumption require additional data as to the hourly and monthly tonnage rates, and kwh. per ton energy consumption rates, for the products to be rolled.

Tinplate Rolling: In one plant operating two 42 in. five-stand tandem cold reduction tinplate mills, the hot strip entering the cold mills ranges from .060 in. to .076 in. thick depending on the final tinplate gauge and the grade of steel, coils weigh about 5000 lb., and the usual rolling speed is about 1400–1500 ft. per min. On favorable orders the 8 hr. turn output occasionally reaches 300 net tons per mill, and over a recent four-month period the 8 hr. turn output per mill averaged 212 net tons of cold reduced strip. Over this four-month period the energy consumption of the main motor generator sets, including exciter and reel booster generator, averaged 95.9 kwh. per net ton of cold reduced strip, and the energy consumption for auxiliaries, including ventilating fans, auxiliary exciter set, heaters, cranes, lights, screwdowns, lubrication pumps, coolant pumps, etc., averaged 16.3 kwh. per net ton, making a grand total of 112.2 kwh. per ton for the cold reduction process.

Another plant also operating two 42 in. five-stand tandem cold reduction mills, reports the energy consumption of the main motor generator sets, not including the exciter and reel booster generator, as 85.9 kwh. per net ton of cold reduced strip. This was the average for a six-month period.

Two five-stand tandem cold reduction tinplate mills in a third plant normally roll from .074 in. thick hot strip, and the coils range from 3500 to 6000 lb. in weight. Over a four-month period the energy consumption of the main motor generator sets supplying the two mills averaged 86.9 kwh. per net ton. Records were kept over a period of several days to determine the difference in kwh. energy consumption for the rolling of different grades of steel, and for rolling to different elongations. For rolling several orders of low carbon copper bearing steel strip, 26 in. wide x .074 in. thick, average coil weight 4000 lb., to .0100 in. thick, at about 1060 ft. per min. delivery speed, the average rolling rate was 23.9 net tons per hour, and the average energy consumption was 94.6 kwh. per net ton. For rolling several orders of high phosphorous steel strip, 29½ in. wide x .074 in. thick, average coil weight 3525 lb., to .0106 in. thick, at about 1000 ft. per min. delivery speed, the average rolling rate was 22.0 net tons per hour, and the average energy consumption was 98.0 kwh. per net ton. Thus rolling to a lesser elongation the energy consumption for rolling the high phosphorous steel was about 3.6 per cent higher, and for the same elongation the energy consumption would be at least 7.5 per cent higher than for rolling the softer grades of steel.

A typical four-stand tandem cold reduction tinplate mill, normally operating at about 1400–1500 ft. per min. delivery speed, and rolling .072 in. thick hot strip to usual tinplate gauges averaging about .010 in., has achieved maximum monthly outputs of 20,000 net tons, and a maximum 8 hr. turn output in excess of 350 net tons of tinplate strip. Over a seven-month period the average turn output has been about 217 net tons. Coils average about 6250 lb. Also during this seven-month

period the energy consumption of the main motor generator set, including exciter and reel booster generator, averaged 91.75 kwh. per net ton of cold reduced strip.

Another four-stand tandem cold reduction tinplate mill, normally operating at slightly lower speed, and rolling coils averaging about 4200 lb., reports total main drive and auxiliary energy consumption, average for a four-month period, of 105 kwh. per net ton of cold reduced strip. This is total for the cold reduction process, and includes the input to the 3500 kw. main motor generator set, auxiliary exciter and booster generator set, heaters, ventilating fans, screwdowns, lubrication pumps, cranes, lights, etc.

A 54 in. four-stand tandem cold reduction mill was originally intended for rolling heavier gauge strip, but recently has been primarily engaged in the production of light gauge strip for tinning. The hot strip entering the cold reduction mill is normally .070 in. thick, the coils average about 6500 lb., and the usual rolling speed is about 1150 ft. per min. During a recent six-month period the main drive energy consumption, including the main motor generator set, exciter set, ventilating fans, and heaters, averaged 100 kwh. per net ton, and the mill auxiliary energy consumption, however not including cranes or lights, averaged 4.6 kwh. per net ton, making a total of 104.6 kwh. per net ton. Also during a 176 hr. test period, in which the mill rolled 3633 net tons, the energy input to the main motor generator set averaged 83.3 kwh. per net ton. In considering this data, it should be observed that the tonnage rolled is taken as the weight of the hot strip entering the cold mill, so that the above unit-energy figures should be raised about 3 per cent to make them comparable with data from other mills, where the mill output is taken as the weight of the cold reduced strip.

Another 54 in. four-stand tandem mill also has been principally engaged recently in rolling light gauge tinplate strip. The hot strip entering the cold reduction mill is normally .072 in. thick, and the usual rolling speed is about 1400 ft. per min. Rolling 28¼ in. wide x .072 in. thick hot strip to .0096 in. strip for tinning, the mill has produced 44 net tons in one hour, 294 tons in 8 hr., and 837 tons in 24 hr. Over a six-month period the energy consumption of the 3500 kw. main drive motor generator set averaged 90.2 kwh. per net ton of cold reduced strip.

The paper thus far has been devoted very largely to the performance of tandem type reduction mills, however some data from single stand reversible mills also may be of interest. On one installation, the two 42 in. reversible mills operate up to about 900 ft. per min. maximum speed, and normally roll .065–.070 in. thick hot strip to usual tinplate gauges in three or four passes. Over a recent four-month period, the 8 hr. turn output averaged 55 net tons per mill, and the energy consumption of the main motor generator sets, including exciter and reel booster generator, averaged 94.7 kwh. per net ton of cold reduced strip. Auxiliary energy consumption for ventilating fans, auxiliary exciter set, heaters, lubri-

FIGURE 13

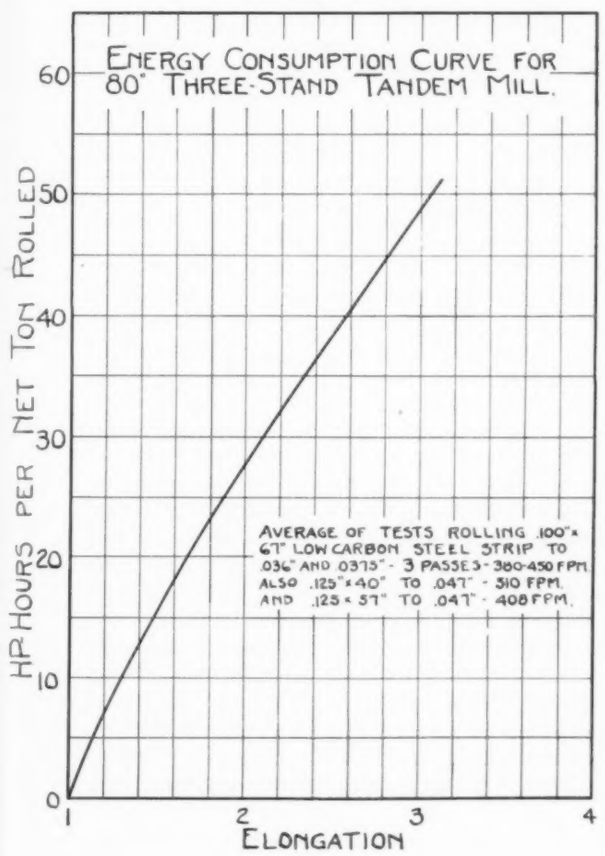
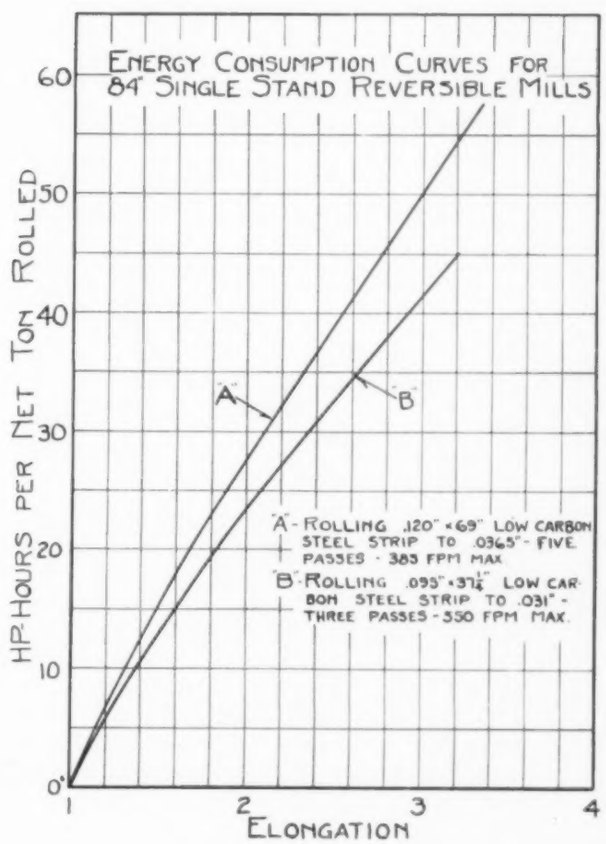


FIGURE 14



cation and coolant pumps, screwdowns, coil handling and recoiling equipment, cranes, and lights, averaged 55 kwh. per net ton, bringing the total energy consumption to nearly 150 kwh. per net ton.

In another reversible mill installation, the 42 in. reversible mill operates up to about 1150 ft. per min. maximum, and rolls extremely heavy .125 in. thick hot strip to usual tinplate gauges averaging .010 in., normally requiring seven passes to effect this total reduction. Coils average about 5250 lb. Over a seven-month period, the 8 hr. turn output has averaged 44.2 net tons, and the energy consumption of the main motor generator set, including exciter and reel booster generators, has averaged 136.6 kwh. per net ton of hot strip entering the mill. Considering the total elongation of nearly 13, this output and energy consumption appear quite in line with other mills.

Table V shows the energy consumption in one large plant for each operation in the production of tinplate by the modern cold reduction process, from the pickling of the hot strip through to the sorting, packing, and shipping of the finished tinplate. Note that the kwh. per net ton energy consumption for each operation is on the basis of the output of finished tinplate. The energy consumption is the average for five months' operation.

Wide Strip Rolling: Large three-stand tandem mills usually roll a wider range of products than most of the smaller tinplate mills, hence it is more difficult to definitely evaluate the performance of different mills for comparison. However over a period of several months, different mills may be expected to have somewhat the same average of orders, hence the average performance should be comparable.

On one 84 in. wide three-stand tandem cold reduction mill, rolling the usual range of widths and gauges of wide strip, the average 8 hr. turn output over a four-month period was about 306 net tons of cold reduced strip. Over this four-month period the energy consumption by the main motor generator set, including exciter and reel booster generator, averaged 39.7 kwh. per net ton, and the energy consumption of the auxiliaries, including ventilating fans, auxiliary exciter set, heaters, cranes, lights, screwdowns, lubrication and coolant pumps, coil handling equipment, etc., averaged 14.9 kwh. per net ton, making a total of 54.6 kwh. per net ton for the cold reduction process.

A similar 80 in. wide mill, engaged in approximately the same rolling work, has averaged 303 net tons per turn for a seven-month period, and the energy consumption of the main motor generator set, not however including the exciter and reel booster generator, averaged 33.5 kwh. per net ton. In this case the mill tonnage is on the basis of the weight of the hot strip entering the cold reduction mill, and hence should be reduced by 2 to 3 per cent to put it on the basis of the output of cold reduced strip. Until recently the best eight-hour turn output was 616 net tons, and during September the mill established a new production record by rolling 809 net tons in an 8 hr. turn, and 2132 net tons in a 24 hr. day.

Over a recent six-month period a 75 in. three-stand tandem cold reduction mill has averaged 369 net tons of cold reduced strip per 8 hr. turn, and the energy consumption of the main motor generator set over this period has averaged 35.4 kwh. per net ton. In a month of full time operation the mill has rolled in excess of 31,000 net tons. In one 24 hr. day the mill produced 1652 net tons, and during this day 707 net tons were rolled in an 8 hr. turn and 110 net tons were rolled in one hour. The product during this period was 64 in. wide x .039 in. thick, rolled from .093 in. thick hot strip, and was rolled at about 450 ft. per min. average delivery speed.

The output of a 93 in. three-stand tandem mill has averaged over 350 net tons per turn during a month of good operations, and over the past year and a half the output has averaged 275 net tons per turn. The main drive energy consumption, including the ventilating fans, exciter set, and heaters, as well as the main motor generator set, averaged 37.5 kwh. per net ton during the month of best production, and over the 18 month period averaged 39.6 kwh. per net ton. In this case the tonnage is reported on the basis of the weight of pickled hot strip entering the cold reduction mill.

During recent months this 93 in. mill has rolled a considerable tonnage of 25–36 in. wide x .016–.024 in. thick strip for galvanized roofing sheets, etc., as well as the wider heavier gauge strip for which the mill is particularly suited. During one week's operations the mill worked for about eleven turns rolling 38–79 in. wide x .093–.105 in. thick strip to the usual .036–.040 in. thick sheet gauges, and the energy consumption of the main motor generator set averaged about 32.5 kwh. per net ton of hot strip. For the other five turns 28–30 in. wide x .065–.070 in. thick strip was rolled to .017–.020 in. thick strip for galvanizing, and the energy consumption of the main motor generator set averaged 53 kwh. per net ton of hot strip. The upper part of Figure 15 is a section of a graphic wattmeter chart showing the kilowatt input to the synchronous motor driving the 3500 kw. main motor generator set for an 8 hr. period during which 72 coils of 28⅝ in. x .065 in. hot strip, weighing 453,340 lb., were reduced to .017 in. thick, for galvanized roofing sheets. The lower part is a similar graphic wattmeter chart for another 8 hr. period during

TABLE V

Energy distribution in tinplate production

Process	*Kwh. per net ton*
Raw coil Pickling	5.0
Cold reduction—Main drive	94.6
Auxiliaries	12.3
Electrolytic cleaning	9.0
Annealing	5.8
Temper rolling—Main drives	13.0
Auxiliaries	3.6
Tr'mming and shearing	6.8
White pickling	1.0
Tinning	7.6
Finishing, sorting, packing, and shipping	12.6
Grand total	171.3

Energy consumption for all processes based on net tons of finished tinplate.

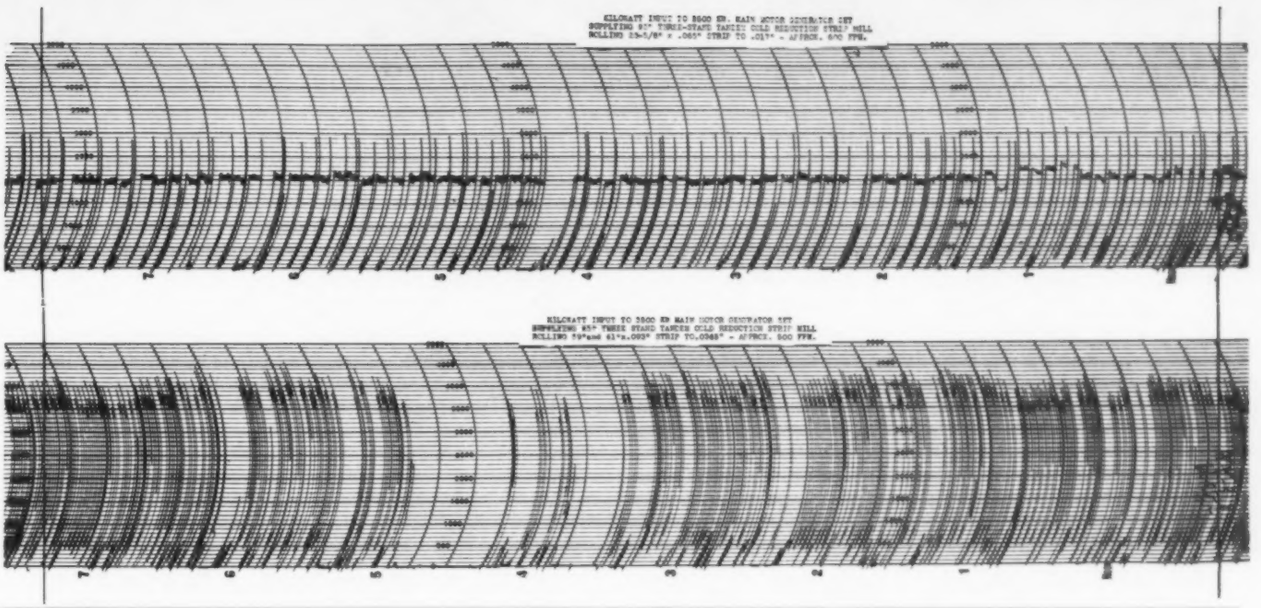


FIGURE 15—Two graphic wattmeter charts showing kw. input to motor generator set drive with different rolling schedules.

which 113 coils of 59 in. and 61 in. x .093 in. hot strip, weighing 834,340 lb., were reduced to .0365 in. thick for automobile sheets.

SUMMARY

Summarizing the above data for the cold reduction of narrow strip for tinplate, we find that the average energy consumption is practically the same for rolling in either four-stand or five-stand tandem type mills, or in single stand reversible type mills. The net energy for the usual cold reduction of mild steel strip to about 7.5 elongations is on the order of 97 hp. hr. per net ton rolled, and the gross input to the main motor generator set, including exciter and reel booster generator, averages about 92 kwh. per net ton of cold reduced strip. The rolling of Bessemer, high phosphorous, and other similar harder grades of steel may increase the power requirements by 10 to 20 per cent over that for mild open hearth steel. Present tandem mills operating at around 1500 ft. per min. delivery speed consistently produce from 200 to 225 net tons per 8 hr. turn, and with the trend toward heavier coils and higher rolling speeds, average turn outputs of 300 tons or more may be expected.

Similarly for the rolling of wider heavier gauge strip for sheets, we find that the average energy consumption is practically the same for rolling in either three-stand tandem type mills, or in single stand reversible type mills. The net energy for the usual cold reduction to about 2.75 elongations is on the order of 39–43 hp. hr. per net ton rolled, and the gross input to the main motor generator set, including exciter and reel booster generator, averages about 36–38 kwh. per net ton of cold reduced strip. On favorable schedules, such as 60 in. wide x .0375 in. thick, maximum output may exceed 100 net tons per hour, although over extended periods, the average output of present mills usually does not exceed 35–45 net tons per hour.

DISCUSSION

PRESENTED BY

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R. H. ELLIS, *Electrical Engineer*, United Engineering and Foundry Company, Pittsburgh, Pennsylvania.

A. F. KENYON, *Steel Mill Engineer*, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

M. STONE, *Manager*, Development Department, United Engineering and Foundry Company, Pittsburgh, Pennsylvania.

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L. R. MILBURN, *Electrical Engineer*, Great Lakes Steel Corporation, Ecorse, Michigan.

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F. MOHLER, *Electrical Engineer*, Steel Mill Section, General Electric Company, Schenectady, New York.

JAMES FARRINGTON, *Electrical Superintendent*, Wheeling Steel Corporation, Steubenville, Ohio.

L. A. UMANSKY: There is hardly anything in Mr. Kenyon's paper to which we can take exception. I have checked several of the power curves against many tests which we have conducted on similar mills. The observed differences between the curves are not much greater than those encountered between several test data obtained by the same party. No test data can be relied upon in making power calculations for new mills without allowing 5–10 per cent or more for variations in energy consumptions due to the possible differences in rolling

practices, lubricants, etc. Mr. Kenyon's method of carrying out the tests and calculations is straightforward and correct. But, while we may check him very closely on the total power required to reduce, say, a .072 in. thick strip to a tin plate gauge, we may differ to a greater extent on the power required by each of the several mill stands. After all, the latter values depend not only on the reductions made but on the tension between the stands. The tension values have been, of necessity, assumed by Mr. Kenyon, since not many of the mills used in making tests are equipped with tensiometers.

Regarding the preparation of the power curves, I have the following comment to make. I believe it to be more convenient to plot the specific energy consumption; *i.e.*, hp. hr. per net ton rolled, not against the elongations, as done by Mr. Kenyon, but against the actual thickness of material, plotted in fractions of an inch. There are two reasons for favoring this method of curve plotting. First, it saves time; you do not have to calculate the elongations, you deal with the values from which you actually start, *i.e.*, thicknesses. The second advantage, intrinsically more important, is that with this method less confusion is apt to arise in comparing different power curves, and there is, therefore, less danger of using a wrong curve. For instance, it would be an error to use a curve, correct for reducing a .062 in. strip to .010 in., for a case of rolling a .125 in. material to .020 in. thickness, even though the elongation is 6.2 in either case.

I am quite certain that Mr. Kenyon fully appreciates the difference in power required in either case, and uses two different curves for the two cases. But if the curves get into less experienced hands, erroneous results and then wrong conclusions may be readily arrived at.

W. A. PERRY: Hot strip mill information has been available for some time, but it is only recently that the veil of secrecy and mystery has been lifted from the cold mills and the information allowed to fall into hands other than those actually connected with the cold mills in their own particular plants. Even visitors were not allowed in these mills. The Inland Steel Company was one of the first, if not the first company to open its pickling, annealing, and cold strip rolling departments to general inspection by the public and engineering societies, both in large groups and individual visitors. These inspection trips are valuable to all concerned, in that they give the visitor an opportunity to see for himself the location of equipment, control devices and positions of operating crews. But it really takes engineering papers, such as Mr. Kenyon and other engineers have prepared and placed before our society, to give us "cold turkey" facts to check over, in order that we may see just how good or bad our practice is.

In the early part of the paper, in Table I and Table II, are listed the mills as to their owners, where and when installed, and pertinent information pertaining to roll diameters, speeds, motor sizes and motor-generator sets. In looking through these tables we find that there is still a great deal of difference in horsepower installed for the same size mills in the different plants, and, no doubt, that is generally accounted for by differences in rolling technique or lubricants used on the strip. The roll designer enters into the picture at this point, for his application of the properly turned rolls greatly influences the product obtained from the mill, and the power required. No doubt, we could also start a separate discussion at this time of the relative merits of anti-friction bearings versus sleeve bearings; several of the plants having both, and each type having its particular outstanding advantages.

In the earlier days, the horsepower ratings per stand could be lower, because the interval between the smaller coils then being rolled, was great enough to allow the motors to cool. Now, with the belt wrappers, improved tension reels, welded coils, improved electrolimit gauges, all tending to make higher speeds possible at a more continuous rate, the mill stands must have larger motors for successful operation. Improvements in acceleration and deceleration of the mills also impose a harder duty cycle on the motors and tend to ask for increased horsepower of the mills.

An analysis of the various curves in this paper shows that for comparative figures, excluding those of Bessemer steel, these curves are sufficiently close together, so that a single composite curve can be used. Available Inland data obtained from previous tests in our files, indicate that over-all, our curves would practically coincide with those shown by Mr. Kenyon. Test on rolling tin plate strip on the 40 in. 5-stand tandem mill, gives an energy consumption curve that is below the composite curve obtained from this article. If both sheets were similarly corrected for motor losses and mill friction losses, we would expect these curves to come closer together. The same is practically true with our 54 in. 4-stand tandem mill. Data on our 72 in. 3-stand mill give a curve that is slightly above the composite curve. Here again, correction in losses may take up the difference. No tests have been made to date by Inland to determine the difference in load while rolling different grades of steel and none to determine the effect of anti-friction or sleeve bearings on the mill rolling.

In conclusion, it may be stated that, on the whole, results obtained from available Inland data, compare quite favorably to the results that Mr. Kenyon has listed in his paper, even though motor sizes of the different mills may not be comparable, indicating that practically the same amount of over-all work is being done, in order to obtain like products.

F. D. EGAN: In reviewing Mr. Kenyon's paper, I was amazed at the wealth of data that he has compiled on power requirements of cold strip mills of all types and sizes, and can appreciate the time and effort required to prepare this data and this paper. We have needed a paper of this type to guide us in the selection of motor sizes and speeds for cold mill drives and it is my opinion that the data presented here will be highly appreciated in the steel industry.

I was rather surprised to see that the power requirements of various type mills rolling comparable strip sizes held so close together, and I believe that, at least part, can be accounted for by the cooperation of the various companies in exchanging operating data through the Association of Iron and Steel Engineers.

I would like to ask Mr. Kenyon if he has any explanation why the energy consumption for rolling tinplate is less than for galvanizing stock, and for the still thicker body stock, using the same type steel and same elonga-

tion, as indicated by his data. Also, in compiling this data, did he observe whether the delivery speed of a particular mill affects the energy consumption?

R. H. Ellis: Our company has also taken considerable data which checks very closely with Mr. Kenyon's. However, regarding the use of this data there are a few precautions which I would like to bring to your attention. In choosing a power curve it is very important that the electrical engineer know exactly what the mechanical engineers want to roll on the mill so that he can choose a curve that is distinctly applied to that rolling. For instance, the .072 in. curve should never be used when calculating for original thickness of .100 in. Neither should it be used for .08 in. or .125 in. thickness. Also the elongation curve should not be extended too far because the minute the elongation is longer than the curve data then the result is entirely out of the range of the test data.

The tabulations which Mr. Kenyon has made up showing speeds and gear ratios can be utilized to make up a speed cone curve. This curve would be of great value when figuring the gear ratios of a new mill.

We are troubled with the request to build a mill that will roll all sorts of original thicknesses down to all sorts of minimum gauges, but it is very difficult to get the mechanical men to specify the entry and delivery thickness of the material to be rolled on a proposed mill. After a mill has been built to roll tin plate, that is, from .072 in. to .010 in., it may be impossible to roll body sheets which are .100 in. entering rolled to .032 in., especially if the speed cones have not been set properly.

In closing, I would like to emphasize again the importance of having the mechanical engineer or roller give us very definite detailed information regarding sizes and schedules so that proper motors and speed ranges can be chosen.

A. F. Kenyon: Mr. Umansky and Mr. Ellis have both emphasized that the energy consumption curves must be used with discretion, and only for making power calculations where the conditions are similar to those under which the test data was obtained. This was mentioned in the paper, and additional emphasis is not out of place.

Mr. Umansky has also commented regarding the plotting of the curves, suggesting that the abscissae be plotted in terms of the actual thickness of the strip after each pass instead of in terms of the elongation. There is no objection to using the actual strip thickness in plotting the curves, although for general use we doubt if there is any appreciable time saving in making the calculations. The energy requirement for the same elongation is practically the same regardless of the actual entering thickness, for a small range of thickness, say from .08 in. to .09 in., so that by using elongation as the abscissae, a test curve obtained from rolling say .074 in. thick hot strip, would be applicable for power calculations for rolling slightly thicker or thinner hot strip, whereas if the curves are plotted using actual strip thickness, some interpolations are necessary before data can be read from the curve.

In connection with one of the curves, Figure 11, we mentioned that some forty sets of test data were observed for this particular mill. About half of the orders were rolled from .093 in. thick hot strip and the remaining orders were rolled from .105 in. thick hot strip. The data was analyzed separately, and two curves were plotted, one for each entering thickness, using elongation as the abscissae, and it was found that the two curves checked very closely. Using actual thickness as the abscissae, the two curves would of course be displaced from each other, and approximately parallel, and additional curves would have to be interpolated between these two test curves to provide data for making calculations for any intermediate entering thickness.

Mr. Egan raised a question as to the difference in the curves for rolling various products. I have endeavored to report the data as it was observed on the different mills, and not to explain why the curves are different. As a partial explanation, however, I rather think that the proportionate drafting in the several passes has some effect on the shape and magnitude of the curves, so that if a certain elongation is effected in say four relatively light passes, the curve may be different than if the same elongation were effected in two or three much heavier drafts.

M. Stone: I should like to ask Mr. Kenyon if, in any of his information, he has attempted to correlate the strip tension with the necessary power to roll. I believe that this will be an important correlation, and further assume that the curves as plotted were net hp.—*i.e.*, the main motor hp. plus the front reel hp. minus the back reel hp., in all cases. I remember a demonstration that Professor Trinks mentioned not so long ago that was very effective. He had a little model mill and was rolling some light material and instead of using motors he used weights around pulleys as prime movers. That is, he attached a wire to the front end of the material and ran it over a pulley to provide front tension. He had a weight hanging on a wire wrapped around the work roll shaft to provide the torque at this point and further had provision for attaching a weight over a pulley by means of a wire to the back end of the material being rolled. He first rolled the material with only the front tension and work roll weights being used and noted the speed of the material going through the mill. Then, he hung the weight on the wire providing back tension, leaving the other weights the same as before. The surprising thing was that instead of the little mill slowing down it speeded up, which indicated that in spite of the fact it had to pull an additional weight, the reduction in rolling power required more than offset this additional weight indicating the sizable effect of back tension, particularly on rolling power.

Now this is all in the right direction because it tends to reduce the hp. rather than increase it. The effect of front tension is presumably very much less on the power to roll, although it certainly has an effect on the flatness of the material being rolled and it might be well, wherever possible, to assemble data of this general nature.

A. F. Kenyon: Operating data as to the value of the strip tension and its effect on power requirements, is very meager, particularly for tandem type mills. The necessity for relatively high tension, particularly on the strip entering the mill, is generally recognized, and as more mills are equipped with tensiometers, and more complete data accumulated, a further paper would undoubtedly be of interest to mill operators.

G. E. STOLTZ: While the data submitted by Mr. Kenyon is a resume of tests made at a number of plants, the results obtained check so closely that more consistent results could hardly be expected if the tests were made on one mill.

This indicates that the design of the mills are of a very high order and that the friction of the bearings is small, otherwise a difference in the results would be obtained. It also indicates that the rolling practice on all the mills tested is good and essentially the same.

We appreciate the splendid response we received from the various steel companies and their engineers in providing this data. The fact that this information comes from so many different mills substantially increases its value to the members of this Association.

L. R. MILBURN: During the past few years there have been installed many cold mills which were practically duplicates. On these mills the mill manufacturer recommended the installation of duplicate motors for all three stands. In actual practice we have found that the motors on No. 1 and 2 stands are doing all the work and should be considerably larger. Possibly we should have had the information contained in this paper four or five years ago; thus, I believe our cold mill installations would have been considerably changed.

Take, for instance, a hot strip mill; as you know, there have been published certain calculations, certain curves and other related information so that you can sit at your desk and figure out the actual horsepower required for each individual stand by very simple means.

It would seem, as far as cold mill installations go, that the electrical engineers have failed to get the essential data early enough to avoid the conditions which we now have; or, is it possible that the cold mills were forced upon us with such rapidity that we were unable to collect this data?

A. F. KENYON: As has already been intimated, the paper was not intended to suggest how the mills should be operated, but rather to report the power requirements as found on different mills. It is quite obvious that a 50 per cent draft will impose a heavier load than a 25 per cent draft. Similarly with heavy tensions on the strip, there may be considerable power interchange between stands, with resultant increased loads on some motors and reduced loads on others.

Mr. Milburn has commented that whereas on his mill all three mill motors are of the same rating, actually the motors on stands No. 1 and 2 are severely overloaded, while the No. 3 stand motor is of more than ample capacity. The general overloading of the motors is probably due to the present operation at rolling speeds higher than originally contemplated, and rolling from heavier hot strip with resultant heavier reductions. The mis-proportionment of the motors on the three stands can be attributed to the desire for duplicate equipment, and also to present practice in drafting being different than considered desirable a few years ago. For instance, a few years ago usual practice was to make only a moderate reduction in stand No. 1, and heavy reductions in stands No. 2 and 3, while present practice is to make extremely heavy reduction in stand No. 1, moderate reduction in stand No. 2, and very light draft, often not more than 8 to 10 per cent, in stand No. 3. The newer mills are therefore being provided with greater total motor capacity to enable rolling maximum width strip at full speed, and are also driven by motors of different ratings to provide the power actually required by the different stands.

L. R. MILBURN: Is it your contention then that these curves, or similar curves, can now be worked out so as to answer our problems in the laying out and installing of new cold mills, working on the same principle that we now use for determining hot strip mill drive capacities?

A. F. KENYON: If the mill operators can state definitely the products to be rolled, speed for each product, reductions in each pass, and tension between stands, then I believe that sufficient data is available to enable calculations to determine the motor loads with accuracy sufficient to assure application of the proper motors and other equipment.

H. W. NEBLETT: Mr. Kenyon's paper is quite a contribution to the subject of cold reduction of steel strip. I think, however, that one of the things that is very important with all of us, and which we know very little about, is a thing he assumed, and we are doing the same in our plant, as I believe the rest of you are; that is, we are assuming the amount of strip tension between stands. This has become quite a problem with us a number of times. We are constantly endeavoring to determine what tension should be on the strip between stands. It probably should be different for the different gauges and should bear a definite relation to the amount of reduction made on the steel strip.

We have found there is a difference in the surface structure of the steel, depending upon the amount of tension applied. In other words, a certain amount of reduction has been made by tension and a certain amount by actual reduction in the rolls. There is evidently a definite relation between these two methods of reduction that should be determined.

I think this has been mentioned before at other meetings, and so far I do not believe it has been answered. I believe it would be a valuable addition to the present available data on cold reduction if we could agree on some formula by which we could say there should be a certain amount of tension, maximum and minimum, in the strip between stands.

F. MOHLER: Mr. Stone brought up this question of the relative tensions, and the effect it had on rolling, and I am heartily in agreement. We have not paid enough attention to what tensions are required for rolling, from either the rolling power standpoint or its effect upon ideal gauge. If we are going to make a detailed calculation of horsepower and then assume the tensions we are going to use between stands, we can probably be farther off than if we took the composite curve, which has been under discussion. A lot has been said about the relative effect between starting with thicknesses of .100 in. or .080 in. and so forth. I think the errors you get from that will fade into the background, as compared to the errors you get from different tensions. Very substantial tensions are being used in rolling, and tension is a real factor that must be taken into account in making power calculations, as well as

(*Please turn to page 47*)

MODERN GAS MIXING SYSTEMS
As Applied to
STEEL PLANT REQUIREMENTS

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CHICAGO, ILLINOIS

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▲ HEAT, like sunshine, is the vital something that is required to transform natural elements into materials and products for the benefit and service of man. Gas as the source of heat is now coming into more general use in steel plants due to the availability of cheaper fuels such as natural gas and refinery gas. In order to use these gases more efficiently, it is often necessary to dilute them with air or some lower heating value gas to a value which would make them interchangeable with other gases used as a base fuel in the plant.

The most important characteristic of gas is its heating value as expressed in Btu. per cu. ft. So, in mixing various gases, it is necessary to have an accurate measurement and control of the quality of the finished product, the mixed gas. The most important tool then, is the device which measures this heating value and does something about ft. There are three such instruments in general use.

MEASURING DEVICES

The recording calorimeter is well known in the steel industry as well as in the gas industry, and its records are generally accepted. The instrument burns a small test sample of the mixed gas and continuously and automatically indicates and records the heating value of that sample in Btu. per cu. ft. at 30 in. of mercury 60 degrees F. saturated. The recorder may be equipped with a contacting mechanism for supervision and operation of gas mixing control.

For control purposes, quick response to change in gas quality is of prime importance, and an instrument has been developed primarily for control of gas mixing with first consideration given to speedy indication of changes even at the sacrifice of other features. It does not indicate absolute heating value, but it does quickly detect changes in heating value, and it is arranged to operate flow control devices. Occasionally the mixing control is used alone, but usually it is supervised by a recording calorimeter, giving a combination of speed and accuracy.

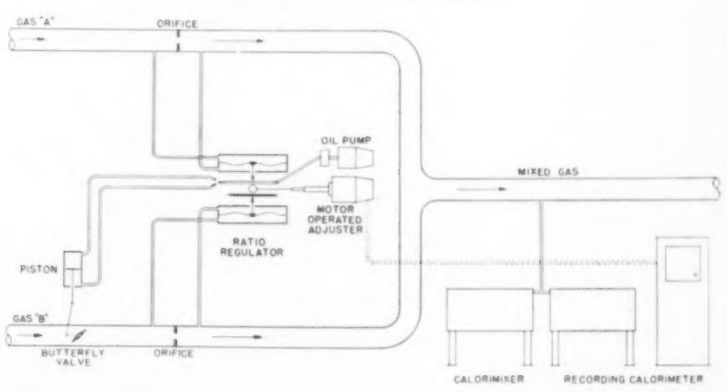
A third instrument has been brought out recently for low cost, to indicate and record heating value for small gas plants. This instrument has been used for mixing control in butane air plants where its low cost is an advantage, but it has not been used in the control of gas mixing in industrial plants.

The three devices mentioned above, operate on a heating value measurement and are unaffected by variables of temperature, pressure and humidity, and so provide the best possible final control.

GAS MIXING SYSTEMS

Starting with a heating value measurement, the first and simplest step in gas mixing is to place a motor operated valve in one of the incoming gas lines and throttle this valve by means of impulses received from the calorimeter or control instrument, to raise or lower

FIGURE 1—Diagram of simple control system for the mixing of two gases under calorimetric control.



the mixed gas heating value. A change in valve setting is required for each change in flow, as well as changes in heating value, but the maximum rate of adjustment is limited by the time lag of the calorimetric device, so this simplified method of gas mixing is limited to those few applications where flow is nearly constant and where all mixed gas goes through a storage holder, so that some hunting is permissible.

The next step is the use of volumetric proportioning equipment, which may be a ratio regulator as shown diagrammatically in Figure 1.

The flows of the two gases to be mixed are measured by the pressure drops across orifice in the gas lines. These pressure drops are impressed on the diaphragm of a ratio regulator. Any unbalance of flows operates an oil jet type pilot device to move a hydraulic cylinder attached to a throttle valve, changing the flow of one gas to re-establish the set ratio of flows.

The controlling calorimeter, burning a sample of mixed gas, detects any departure from the desired heating value and operates a pilot motor to change the ratio setting of the regulator, to correct the mixture Btu.

This type of proportioning control fits a majority of the mixing requirements. However, because of the decrease in orifice pressure drop with decrease in flows, and consequent loss of sensitivity, some other arrangement is required where flow ranges of ten or twenty to one are encountered. Such a system is shown in Figure 2.

The fixed orifices in the two gas lines are replaced by butterfly valves, acting as measuring orifices. The two valves have similar characteristics and are coupled mechanically so that they move together with their areas of opening always in the same ratio. Thus the orifices may be moved without disturbing ratio of flows. A pressure difference regulator, connected across one of the two measuring valves, moves both valves together, to hold a constant pressure drop, and thus maximum sensitivity on the ratio regulator. Calorimetric control, of course, is as previously described. The range from maximum to minimum flow which can be handled by this type of installation is about twenty-five to one, more than enough to cover the requirements of any mill gas distribution system.

Sometimes the percentage of one gas in the mixture must change over wide limits, as is the case when blast furnace gas is enriched with a small amount of coke oven gas to provide a uniform mixed gas. Still another type of proportioning as shown in Figure 3 must then be used to obtain very wide adjustment of ratios.

A fixed orifice is used in one gas line, such as the blast furnace gas line, and the motor operated butterfly valve is used as the measuring orifice in the other, or coke oven gas line. The ratio regulator throttles the coke oven gas regulating valve to proportion the flow as mentioned before.

Again the calorimeter measures the mixed gas heating value. This time the heating value is adjusted by changing the position of the motor operated valve, changing the effective area of that measuring orifice so that a different flow satisfies the ratio regulator.

There have been some unusual installations requiring both wide range in flow and extreme change in ratios of the constituent gases. This also has been accomplished by a control scheme which we will not describe here.

Later in this paper we describe a need for mixing some gases, such as refinery gas and air, to obtain a constant flow factor, even though this means a changing heating value. Figure 4 shows typical equipment to accomplish this.

The volumetric proportioning equipment operates just as previously described, and the ratio regulator is adjusted by the calorimetric control to change the ratio of one gas to the other.

There is a very definite relationship, which may be calculated, between the incoming gas heating value and the desired mixed gas heating value for constant flow factor. This may be expressed in terms of percentage of one gas in the mixture versus desired mixture heating

FIGURE 2—Diagram of control system used where wide variations in rate of flow are encountered.

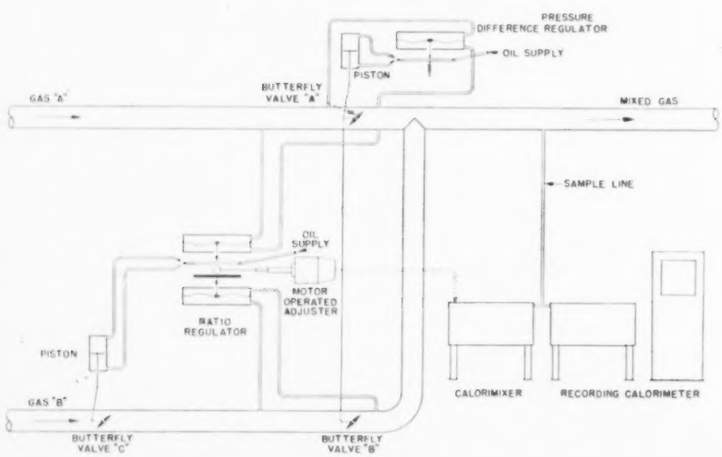
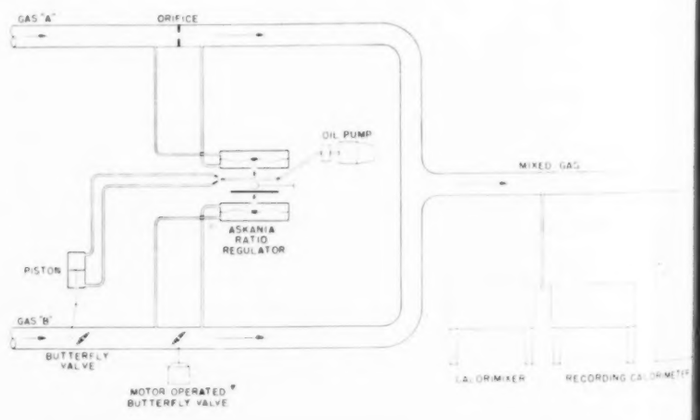


FIGURE 3—Diagram of control system used where wide changes in the percentage of one gas are encountered.



value. The position of the motor operated adjuster on the ratio regulator is a fairly reliable measure of the percentage of each gas in the mixture, so it is possible to use the movement of this adjuster to change the mixture heating value in accordance with a definite, calculated schedule.

This is done by mounting a compensating rheostat on the ratio regulator, to be moved by the motor operated adjuster, and connecting this rheostat in the thermocouple circuit of the control calorimeter. The higher the resistance of this rheostat, the higher will be the mixture heating value required to satisfy the control. In operation, an increase in incoming gas heating value is detected by the calorimetric control which initiates a movement of the adjuster on the ratio regulator, changing the proportion of each gas in the mixture. At the same time, the compensating rheostat moves, calling for a new mixture heating value. In a few steps the control is again stabilized at a new ratio and a new heating value, in accordance with the calculated values for constant flow factor.

Under these conditions, the recording calorimeter measures and records the mixture heating value and is used as a manual check on the operation of the control. Because of the changing heating value, it does not automatically supervise the mixing control.

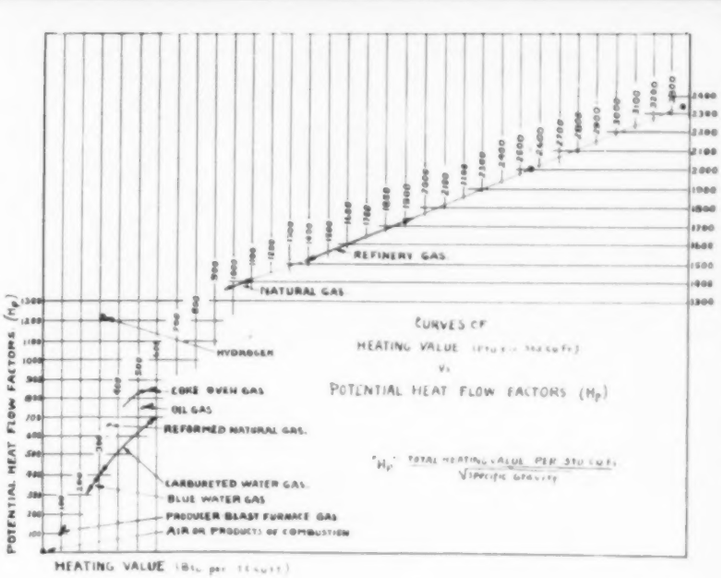


FIGURE 5—Chart showing flow factor values for a number of commercial gases.

THEORY OF INTERCHANGEABLE FUEL GASES

The availability of certain gaseous fuels of widely varying chemical and physical characteristics presents new problems in the utilization of these fuels. Because of number and magnitude of the variations in properties of fuels which affects desired thermal effects it may at first appear that each individual burner and each individual kind of fuel must be treated individually for producing the desired combustion effect. Nevertheless a study of some of the more important combustion characteristics of the different fuels and typical industrial gas burning equipment, indicates that a great deal can be accomplished towards reducing, or eliminating, most of the difficulties involved in the efficient utilization and distribution of available gaseous fuels.

For the utilization of gaseous fuels, total heating

FIGURE 4—Diagram of control system used for maintenance of constant flow factor rather than constant heating value.

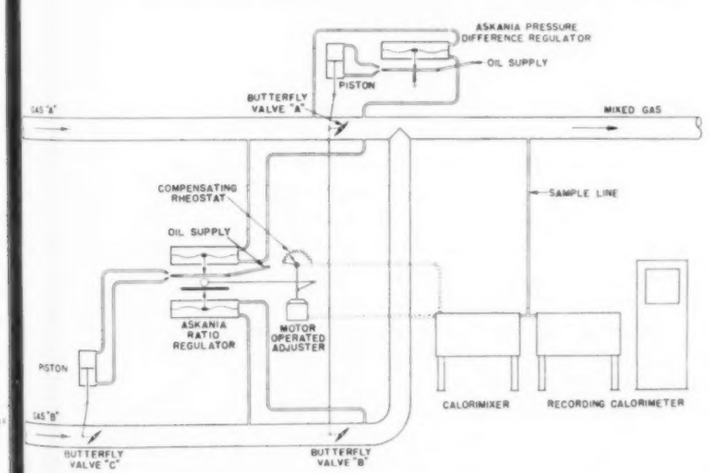
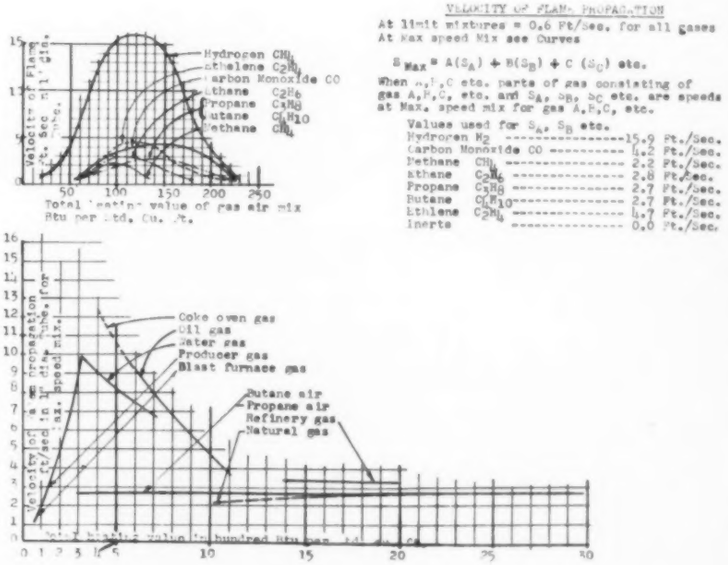


FIGURE 6—Chart showing velocity of flame propagation for various commercial combustible gases.



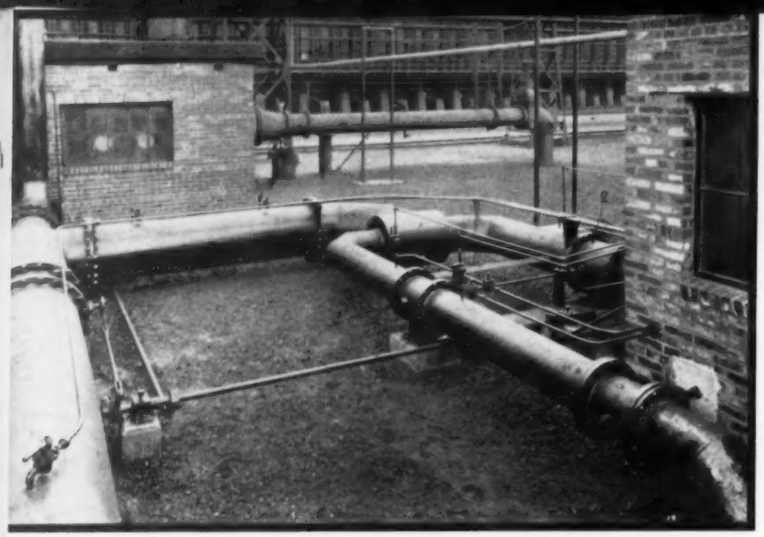


FIGURE 7—View of arrangement of piping and regulating valves in installation for stabilization of refinery gas.

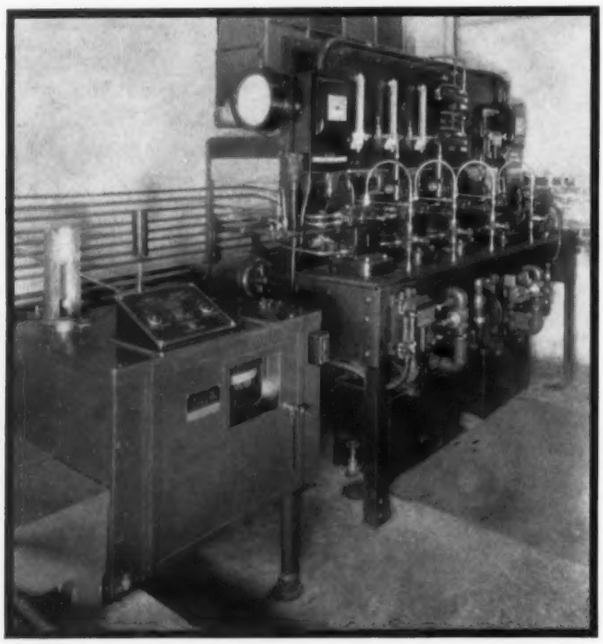


FIGURE 8—This installation of controls and instruments functions to regulate the mixing of air and refinery gas.

FIGURE 9—View showing calorimetric control, regulating equipment and instruments in another installation for the stabilization of refinery gas.

value per unit volume divided by the square root of the density becomes a very important property of a gas. This results from the fact that with practically all gas burning equipment, the volumetric rate of flow of gas varies inversely as the square root of the density. For convenience we will use the term flow factor (potential heat flow factor) to represent this property of the gas.

$$\text{Flow factor} = H_p = \frac{\text{Total heating value per standard cu. ft.}}{\sqrt{\text{Specific gravity}}} = \frac{H}{\sqrt{d}}$$

The heating values of common commercial gaseous fuels vary from 75 to 3320 Btu. per standard cu. ft. Their potential heat flow factors vary from 72 to 2320 representing a change in potential heat flow of 1 to 30. Changes in flow factor would of course, cause changes in heat input and changes in combustion air requirements, providing no changes were made in gas burning appliances. Maintenance of constant flow factor would maintain constant heat input and would materially simplify the gas utilization and distribution problem.

The curve sheet shown in Figure 5 shows flow factor values for a number of common commercial gases. We have included on the curve sheet flow factors for hydrogen and air and inerts. The flow factor for a gas made up of component gases A, B, C, etc., may be expressed as:

$$H_p = \frac{A(H_a) + B(H_b) + C(H_c), \text{ etc.}}{\sqrt{A(d_a) + B(d_b) + C(d_c), \text{ etc.}}}$$

Because of the fact that flow factor varies directly with heating value and to a much lesser extent with the smaller variable density, one may in general assume that for any gas with a high flow factor, this value may be reduced by the admixture of a gas with a low flow factor to produce an intermediate flow factor. By suitable selection of available gases the intermediate value may be selected to correspond with the value for some other available gas, usually the base gas supply, so that the gases with the initially high flow factor will, when mixed with another gas, produce a mixture which when substituted for the base fuel supply will produce substantially the same heat input and which in general will not require any adjustment of burners, gas pressures, or combustion air control.

One point of interest in this connection is the fact that with constant potential heat input, the theoretical combustion air requirements will also remain reasonably constant. In general a higher total heating value is accompanied by an increase in theoretical air requirements. It may be noted that, in the utilization of refinery gases, dilution with air to produce a flow factor the same as that of a low heating value gas helps to increase the air supplied to the burner to partially compensate for the higher air requirement per Btu. of the refinery gas.

In practice it is frequently desirable when designing gas stabilizing equipment to change the flow factor value for the substitute fuel in a manner so that the heat input differs slightly from that of the base fuel supply, to compensate for difference in air requirements of the two fuels, and to compensate for air in the stabilized gas, when air is used for stabilization. Compensation for differing air requirements is particularly valuable where fuels are used for atmosphere control.

In practice automatic gas stabilization has been confined primarily to the use of butane, propane, refinery and natural gas as substitutes for low heating value artificial gas. In most instances air has been utilized as the stabilizing medium. Other combinations of gases could be used to accomplish similar results. As an example, the use of water gas and natural gas as a substitute for coke oven gas offers not only stabilization of heat input but some tendency to equalize velocity of flame propagation. Incidentally, it would appear that stabilization of refinery gas with air to be interchangeable with coke oven gas tends to increase velocity of flame propagation to more nearly approximate that of coke oven gas. There continues to be a great deal to be known about the velocity of flame propagation and the effects of variations on the use of fuels. With air-gas limit mixtures velocity of flame propagation for all gases are substantially the same, namely, .65 ft. per sec. (measured in a 1 in. diameter tube). At air-gas mixtures for maximum speed, velocities vary over fairly wide limits. Most pure gases range from 2.2 to 5 ft. per sec. with hydrogen an outstanding exception with a velocity of 16 ft. per sec. The performance of gas burners with variation in velocity of flame propagation will obviously depend on individual burners, in particular to a considerable extent on the quantity of primary air and air used in the stabilizing process, and on the relative direction of travel of secondary combustion air when they meet. Thus it is possible to produce long lazy flames with gases of low and high maximum velocity of flame propagation. On burners using the fuel and all combustion air in a premix, little can be done to stabilize flame length, but in the utilization of fuels of this type, flame length is usually of minor importance. Where much of the combustion air enters as secondary air it is frequently possible to adjust individual gas burning equipment and select the stabilizing gas to make heat dissipation substantially independent of the composition of the available fuels.

Other properties of the gas, such as flame temperature, volume and specific heat of the products of combustion, radiant energy of the flame, etc., are sometimes of some importance in the utilization of gaseous fuels. These factors are usually of minor importance, or present a problem for the combustion engineer which is difficult or impossible of solution. In practice they are not of sufficient importance to prevent the satisfactory use of gas stabilizing control.

By the selection of suitable stabilizing gases, it is therefore possible to take available fuels and premix in accordance with a fixed selected plan to produce and distribute fuels which are substantially interchangeable for general combustion purposes.

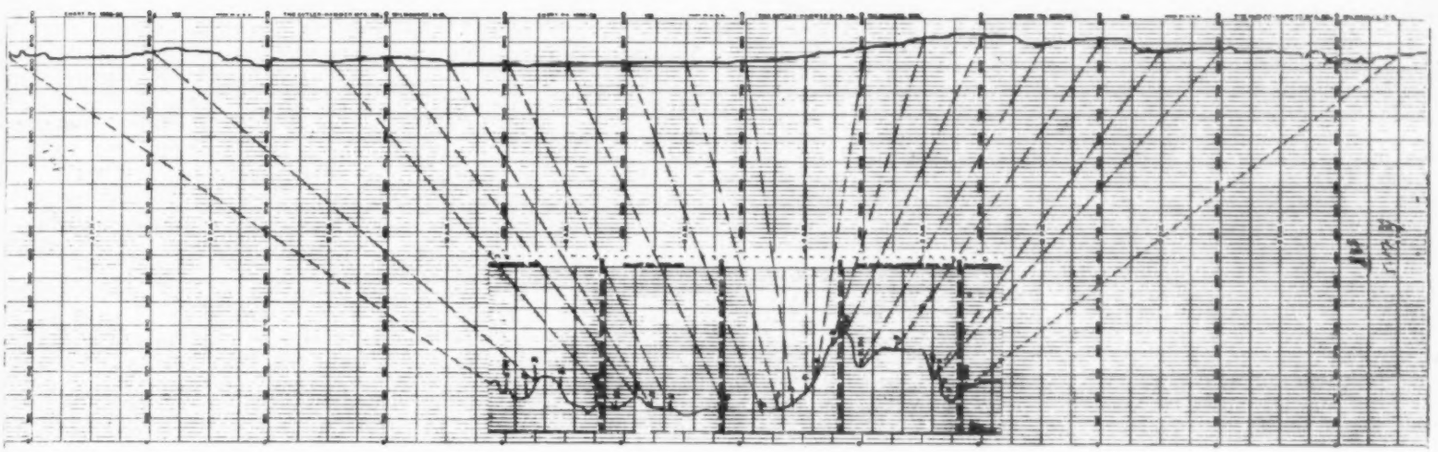


FIGURE 10—Charts showing relationship between heating value and gravity of incoming rich gas and heating value of stabilized gas.

The design of suitable automatic control equipment involves a study of each individual problem. Since total heating value directly affects all combustion processes, and in general varies to a greater extent than other properties of gaseous fuels, we have in our controls used a direct measure of heating value as the primary control factor. The property of a gas second in importance, namely square root of the density, we have included as a secondary control factor, and, for reasons of reliability, safety and cost, have inferentially determined this property from equipment making up the heating value control.

For purposes of discussion it may be desirable to consider the problem of stabilizing a refinery gas supply which varies in heating value from 1400 to 2000 Btu. per standard cubic foot to be interchangeable with a base fuel supply of coke oven gas, 540 Btu., .4 specific gravity. In this case it is desirable to use air as the stabilizing fuel.

The flow factor for the base fuel is then $\frac{540}{\sqrt{.4}} = 854$.

The approximate density of refinery gas may be

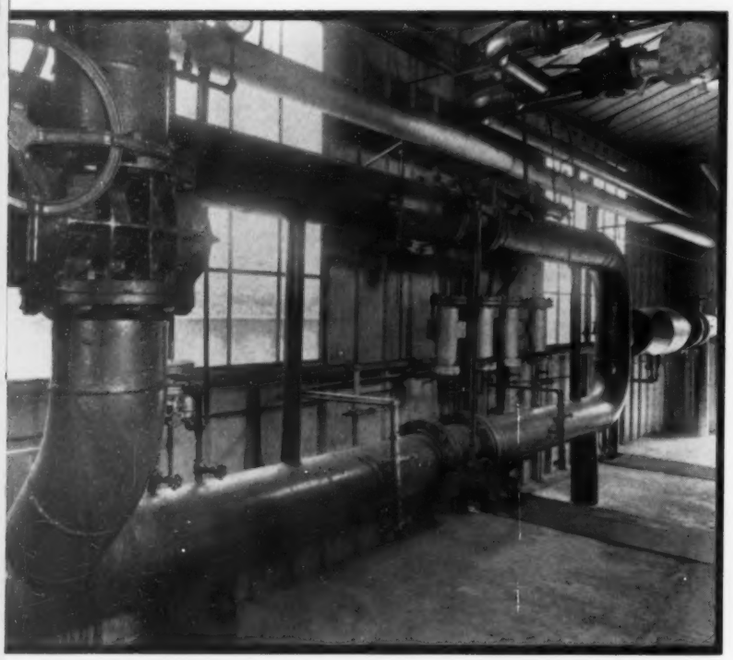


FIGURE 11—General view of piping and regulating valves in another installation for gas stabilization.

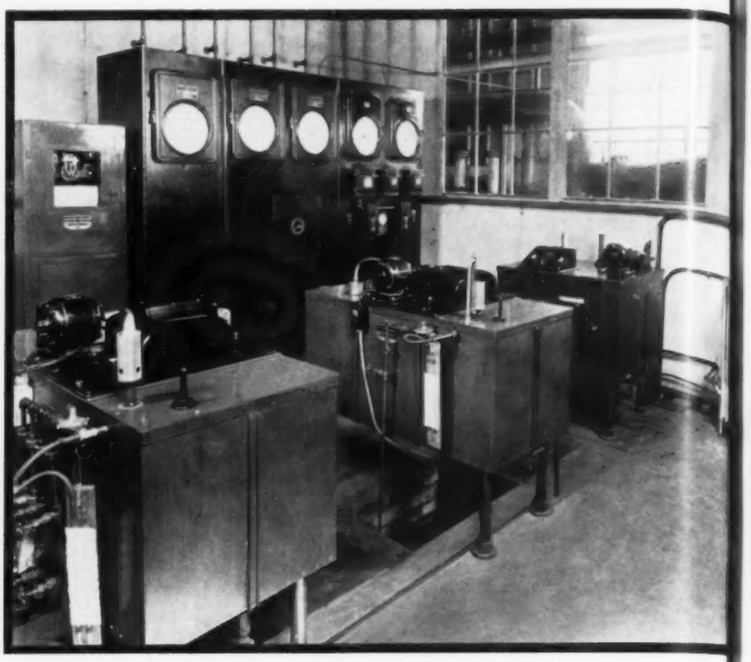


FIGURE 12—This control equipment for gas stabilization includes ratio and pressure regulators, calorimetric control and recording calorimeters.

expressed by an equation relating heating value and specific gravity:

$$\text{Specific gravity} = \frac{\text{Total heating value} - 150}{1500}$$

$$\text{or } d_r = \frac{(H_r - 150)}{1500}$$

in which H_r and d_r are the total heating values per standard cu. ft. and specific gravity of the refinery gas, respectively.

The heating value and specific gravity of an air-gas mix may be expressed as:

$H_m = (1-A)\ (H_r)$, and $(\text{Sp. gr.}_m) = (1-A)\ (d_r) + A$
where A = part of mixture consisting of air.

$$H_p \text{ for mix} = \frac{(1-A)\ (H_r)}{\sqrt{(1-A)\ (d_r)+A}}, \text{ which, for}$$

interchangeability with coke oven gas should equal 854.

For any heating value refinery gas it is possible to calculate per cent of air (A) and stabilized gas heating value to satisfy the above equation. In practice, graphic methods of calculation are most satisfactory.

The air required per Btu. of refinery gas is higher than that for coke oven gas by about 11 per cent. Refinery gas of 1400 Btu. and specific gravity .833, stabilized for flow factor of 854, would have a heating value of 810, specific gravity .904, and 42 per cent air in the mixture. The combustible in the 810 Btu. gas requires (8.10) (0.996) = 8.06 cu. ft. of air per cu. ft. of gas, of which .42 cu. ft. has been supplied for stabilization purposes. The 810 Btu. gas would then require 8.06—.42, or 7.64 cu ft. of air per cu. ft. of gas. This is equivalent to .943 cu. ft. per 100 Btu. which is about 6.7 per cent higher than that for the base fuel coke oven gas. We would then reduce mixed gas heating value further so that the flow factor is approximately 6.7 per cent lower for the refinery air mix than for the coke oven gas or a flow factor of 797, corresponding to 763 Btu. (Mix 54.5 per cent of 1400 Btu. refinery gas and 45.5 per cent air.)

Similarly for any other refinery gas heating value, let us say 2000 Btu., 1.23 specific gravity, the mixture for 854 flow factor would consist of an 897 Btu. gas, with specific gravity 1.105, air 55.2 per cent. The combustible in the 897 Btu. gas would require (8.97)(1.00) cu. ft. of air per cu. ft. of gas, of which .552 cu. ft. has been supplied for stabilization. The 897 Btu. mixed gas would then require (8.97) (1.00)—.552 per cu. ft. of gas, or 8.42 divided by 8.97 or .939 cu. ft. of air per 100 Btu., a value about 6.0 per cent higher than that for coke oven gas. At this value too, flow factor should be approximately 6.0 per cent lower, so that for 2000 Btu. refinery gas the stabilized heating value would be held at 840 Btu., 1.09 specific gravity, 58 per cent air in the mix. Similar calculations may be carried out for intermediate rich gas heating values.

Gas mixed in accordance with these calculations has a potential heat flow in the substitute fuel lower by about 6 per cent than that obtained from the base fuel. The object of this reduction in heat input is to establish satisfactory combustion without any change in gas

burning equipment and for the establishment of constant furnace atmosphere. In providing calorimetric equipment for measuring stabilized gas heating value, and volumetric proportioning equipment for taking care of large fluctuations in the flow of gas, natural means are already included in the equipment for obtaining indications, and power movements, which are used for adjusting the maintained mixture heating value at the desired value. This has been done in a number of different ways depending on local mixing conditions.

Although automatic gas stabilizing has in practice been confined primarily to such substitute fuels as butane, natural gas and refinery gas, it is, of course, possible to apply similar methods to utilization problems involving other gases.

INSTALLATIONS OF GAS STABILIZING AND GAS MIXING CONTROL

During the depression some coke plants under contract to supply local gas utilities with coke oven gas were accumulating such large stocks of coke as to present a very serious situation. In a few instances the problem was solved by producing a substitute gas at reasonably low cost to take the place of coke oven gas for underfiring at the ovens, and for other heating applications in the mills where coke oven gas was normally used. This permitted slower coking schedules resulting in lower coke yield and at the same time released all of the coke oven gas for sale to the gas utilities. By means of gas stabilizing control it was possible to dilute and condition the by-product gases from the local refineries so that they could be used satisfactorily as a substitute for coke oven gas.

One of the earliest installations of gas stabilizing control is in the Indiana Harbor plant of the Youngstown Sheet and Tube Company. Here the incoming gas may consist of straight refinery gas varying in heating value from 2000 to 1450 Btu., or 1040 Btu. natural gas, or a mixture of the two.

The problem was to dilute this rich gas with air to a value where the mixture would be interchangeable with coke oven gas which is the base gas fuel in the plant. As stated above the heating value of the rich gas varies from 2000 to 1040 Btu. and in gravity from 1.2 to .6. Briefly it was necessary to produce a substitute gas which, when supplied to burners adjusted for coke oven gas would pass the same flow of total Btu. and the required combustion air as would coke oven gas.

In Figure 7 is shown the arrangement of the piping and regulating valves, and the manner in which the air and rich gas are brought together for mixing. It is also shown how the mixed gas is piped two ways,—to the tin mill and to the steel plant. Because of its cleanliness and uniformity, only stabilized gas is used in the tin mill where gas burning equipment contains refinements which would be seriously affected by tar and other materials present in coke oven gas. In the steel plant both stabilized gas and coke oven gas are distributed in the same fuel system. Depending on coke plant operations and the demand for gas, the gas distributed in the steel plant varies from 10 to 90 per cent coke oven gas mixed with the stabilized gas. As a consequence the mixing of refinery gas and air must be so controlled as to produce a mixture which would be entirely interchangeable with coke oven gas so as to avoid burner troubles. The stabilized gas has been giving satisfactory results wherever used, including soaking pits, open annealing, reheating furnaces, pipe welding, etc.

Figure 8 shows the arrangement of the control regulators and instruments. As explained earlier in the

FIGURE 13—Diagram showing the distribution systems of the various gases to the consuming departments.

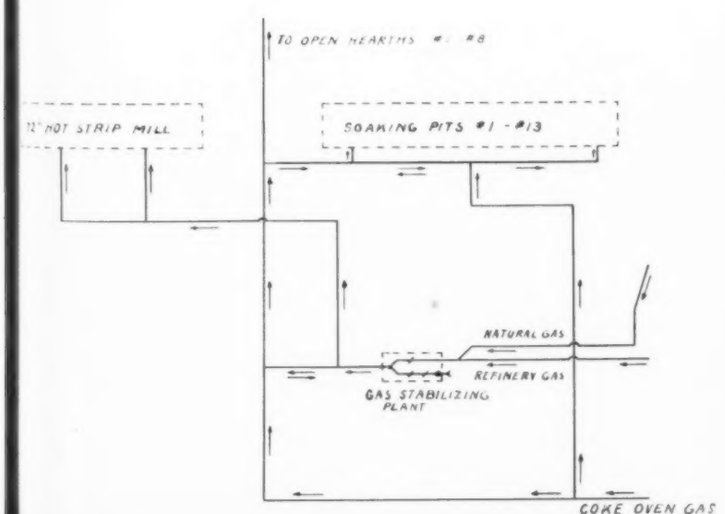
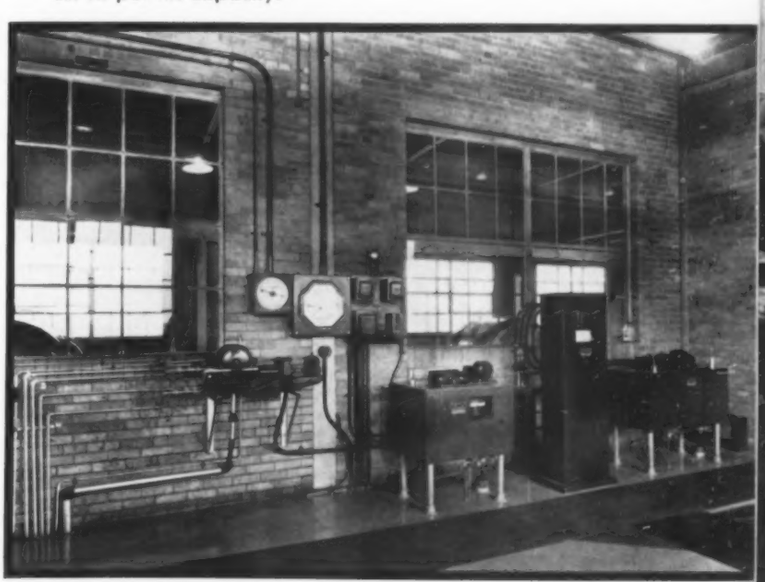


FIGURE 14—This equipment regulates the mixing of coke oven and blast furnace gases in a plant of 3,250,000 cu. ft. per hr. capacity.



paper it is necessary to control the mixture of refinery gas and air so as to maintain a flow factor equivalent to coke oven gas. In other words, the mixed gas must vary as a function of rich gas heating value, gravity and air requirements. This is accomplished by manual adjustment of the control point of the calorimetric controller shown at the left of Figure 8.

A later installation of gas stabilizing control has been made in a plant in the Chicago district. Operating conditions are similar to what they are at Youngstown Sheet and Tube Company, in that the rich gas consists of oil refinery and natural gas and the medium for stabilizing is air. In Figure 9 is shown the arrangement of the regulating equipment, calorimetric control, and recording calorimeters. Some improvements have been added chief of which is the incorporation of automatic stabilizing control to compensate for variations in rich gas heating value, gravity, chemical composition and ombustion air requirements. The functioning of this stabilizing control has been described earlier in this paper and illustrated in Figure 4. In order to provide for continuous gas delivery from the plant and permit routine inspection and servicing of equipment, the regulators, stabilizing control and calorimetric equipment have been installed in duplicate.

The relationship between the Btu. and gravity of the incoming rich gas and the heating value of the stabilized gas is practically illustrated by the comparison of the charts as shown in Figure 10. The graph at the bottom represents the heating value of the incoming rich gas while the upper curve represents the Btu. of the mixed gas as regulated by the stabilizing control. You will note that for every variation in rich gas heating value there is a corresponding change in the quality of the mixed gas as the stabilizing control shifts the control point to maintain the mixed gas close to the desired flow factor value, Btu., gravity, and combustion air relation.

The difference in chart length is due to the fact that the rich gas chart is driven by a mechanism in the calorimeter recorder as a function of gas flow, while the mixed gas chart is a standard chart driven as a function of time. Since the chart from the rich gas calorimeter is used for billing on the basis of therms or total Btu., this weighting of the calorimeter chart in terms of total Btu., greatly facilitiates the work of the estimators. This method of gas measurement also plays an important part in the operation of the plant since the supply of rich gas which can be purchased is limited to a definite quantity expressed in total therms per hour. As a result the operator must know at all times how much gas there is available for mixing at this point.

Stabilized gas is used in both the sheet and tin mills in a wide variety of equipment such as cold reduction, cold rolling, hot mill roll train, open and air blue annealing, bell annealing and for various other operations in the tin house and galvanizing plant. It has been found to be very satisfactory for all purposes and for some operations even superior to other gas fuels. For instance for open annealing natural gas is used at the charge end, and for the final treatment, the stabilized gas, because of its luminosity, is used at the discharge end.

More recently, stabilizing control was installed in the Riverside plant of Otis Steel Company, Cleveland, Ohio. The arrangement of the piping and regulating valves is shown in Figure 11. Before the introduction of refinery gas, natural gas was used exclusively in the 72 in. hot strip mill, and both natural gas and coke oven gas were used in the soaking pits and open hearths. Substituting low priced refinery gas for natural gas wherever possible represented considerable saving in fuel cost and at the same time made for greater flexibility in the distribution of gas. To insure an adequate supply of gas for stabilizing purposes, the natural gas was rerouted through the plant and connected into the refinery gas line. A pressure regulator adjusted for 2¼ lb. admits natural gas only when the supply of refinery gas is insufficient to meet the demand. The problem therefore was to dilute the variable rich gas consisting of refinery gas and sometimes natural gas using air for mixing and stabilizing so as to produce a mixture which would be a satisfactory substitute for coke oven gas in whole or in part.

The control equipment for gas stabilization is shown in Figure 12. On the rear of the panel, are mounted ratio and pressure regulators which operate the flow control valves in the pipeline. The control calorimeter shown in the background at the right, continuously sampling the mixed gas directly after the mixing chamber, periodically adjusts the ratio regulator as described earlier in this paper. The compensating rheostat shown in the square cabinet on the front of the panel is mechanically connected to the adjusting lever on the ratio regulator for stabilizing control. The calorimeters in the foreground record the heating value of the incoming gas and of the mixed gas as it is delivered to the mill.

The distribution of gas in the mill is shown diagrammatically in Figure 13. Normally only stabilized gas is used in the 72 in. mill while coke oven gas is delivered to the soaking pits and open hearths. In the event that the demand exceeds the supply of coke oven gas, sufficient stabilized gas to make up the deficiency flows over into the coke oven gas line and on to the soaking pits. On the other hand when the load drops off and the supply of coke oven gas exceeds the demand at the soaking pits, the surplus backs up and spills over into the line to the 72 in. mill and thereby reduces the demand for gas from the gas mixing plant. Under such conditions the percentage of coke oven gas delivered to this mill may vary as much as from 10 to 70 per cent.

With such a variation in gas to either plant it is obviously necessary in preparing the substitute gas to regulate dilution with air so as to produce a mixture which will have characteristics similar to coke oven gas. Close observation of burner performance in various parts of the plant, where varying percentages of both gases are used, indicates that the stabilized gas is satisfactorily interchangeable with coke oven gas. With a steady supply of coke oven gas as a base fuel, the gas mixing plant can absorb the wide fluctuation in demand without disturbance to adjustments of burners and combustion controls.

At the 1936 Convention of the Association of Iron and Steel Engineers in Detroit, F. J. Harlow presented an interesting paper which described the distribution of gas in the River Rouge plant of Ford Motor Company. In this paper he described the gas mixing station which was designed to mix either propane or butane with air or blast furnace gas to make up for the deficiency in coke oven gas supply while the new coke ovens were

under construction. In order to produce a gas which would be interchangeable with coke oven gas, it was necessary to determine by calculation the settings which were necessary on the control for the four different gas combinations. As a result the substitute gas can be delivered to the plant fuel system in varying quantities without causing disturbance in burner settings adjusted for coke oven gas. After the new coke plant was put in service there has been little occasion to put the mixing station in operation. It has, however, been maintained as a stand-by plant and in readiness for immediate operation. During the coal strike early in 1939, the butane plant was called upon to deliver gas to the plant fuel system to conserve coal stocks during the strike.

Where two types of gas of distinctly different but more or less fixed chemical and physical properties are available it is sometimes possible to materially simplify the utilization problem by combining these two fuels into a single supply of fuel. Such combination not only permits of greater flexibility in allocation of fuels, but also frequently results in a single fuel which has more fixed and desirable combustion characteristics than each of the original fuels. As an example blast furnace gas and coke oven gas when mixed to a constant heating value possesses combustion advantages over the individual fuels. The mixture can be burned with simpler equipment than straight blast furnace gas and at the same time it has slower flame propagation and is less costly than straight coke oven gas.

An installation of this latter type of gas mixing system has been made in the Detroit plant of Great Lakes Steel Corporation. The gas mixing station in this plant has a capacity of 3,250,000 cu. ft. of mixed gas per hr. and during the past year its delivery has averaged 2,000,000 cu. ft. per hr. The problem was to use the entire output of the new coke plant for mixing with gas from the blast furnaces in producing a fuel which would be satisfatcory for general use throughout the steel plant. The quantities of coke oven gas and blast furnace gas available for mixing determined 385 Btu. as the heating value to which the gases should be mixed. In actual practice this value has proven to be very satisfactory for all applications and permits a balance of fuel supplies. Figure 14 shows some of the instruments and control which regulates gas mixing and maintains the correct mixture heating value.

The gases after mixing are boosted in pressure to two or three pounds for distribution to the open hearths, soaking pits, preheating furnaces, annealing and normalizing furnaces. These are all equipped with various types of combination oil and gas burners so that either fuel can be used depending on availability and operating costs. The change-over to mixed gas is being brought about slowly in order to allow for sufficient time in which to obtain experience with the new fuel. It is reported that as the operators become accustomed to the mixed gas they like it very much.

One other application of gas mixing which resulted in a substantial saving in operating cost is an installation in a steel plant in northern Minnesota. In this plant there is a sizable power station which not only supplies all power requirements for the plant but also sells its surplus of electrical energy to a local power company. A battery of gas engines driving electrical generators are propelled by blast furnace gas slightly enriched with coke oven gas. Much trouble was experienced with back-fire and knocking, as one would expect with faulty carbureters or a poor grade of gas. In an effort to correct this condition suitable control was installed to regulate the enrichment of the blast furnace gas to maintain the mixture at 94 Btu. The management reports that from the time the equipment was put in operation there has been a surprising improvement in gas engine performance.

We have tried to outline in this paper a few of the many interesting gas mixing problems that have been met and solved. It is apparent from this discussion that each problem, each set of conditions, and each proposed installation, requires individual study on the part of the manufacturer and user, to arrive at the final answer—satisfactory, economical and flexible usage of gaseous fuels.

DISCUSSION

PRESENTED BY

CARL MENGES, *Fuel Engineer*, Otis Steel Company, Cleveland, Ohio.

A. J. FISHER, *Fuel Engineer*, Bethlehem Steel Company, Sparrows Point, Maryland.

H. J. VELTEN, *President*, Askania Regulator Company, Chicago, Illinois.

P. F. KINYOUN, *Fuel Engineer*, Bethlehem Steel Company, Lackawanna, New York.

G. M. ARNOLD, Industrial Division, Cutler-Hammer, Inc., Chicago, Illinois.

CARL MENGES: Engineers and operators of gas mixing stations such as Mr. Arnold described will probably agree that it takes some time and study, and experience before one becomes familiar enough with the various phases of all of the control equipment; and full confidence in knowledge of the equipment comes only after a more or less tedious study of the mathematical formulae involved.

The introduction of the potential heat flow factor certainly is very original and is, as Mr. Arnold points out, the basis for all their installations. The curves showing the velocity of flame propagation of various gases are highly interesting, since so little information on this important subject is available today.

Stabilized gas, a fuel interchangeable with the base fuel, opened the way for many new installations in industries which are large consumers of gas. The steel industry as one of the largest consumers of fuel readily accepted this new equipment as the installations of the last two years indicate. The reasons for its ready acceptance in the steel industry are as follows:

1. It becomes possible to make the most efficient use of all its own gas available by having an interchangeable standard fuel throughout or in parts of its plants.

2. It makes it possible to feed purchased gas, coke

oven gas, natural gas, or refinery gases through a gas mixing station directly into a wide spread gas system, having this purchased fuel interchangeable with the basic plant gas fuel.

Both items will bring a reduction in costs and give the management a wider margin in selecting the purchase of outside fuels.

Mr. Arnold has shown in his paper the many possible installations of stabilized gas which can be worked out and which fall into two groups:

1. The mixing of existing gaseous plant fuels in certain proportions to obtain a gas of a constant heat flow factor.

2. The mixing of purchased fuels—usually of high Btu. content—with air or low Btu. gas to obtain gas mixtures of the same potential heat-flow factor as the selected base gas.

The installation at the Otis Steel Company uses refinery gas and natural gas and stabilizes them with air, having the mixtures interchangeable with coke oven gas as the selected base fuel.

This stabilized mixture is fed directly as make up fuel into our main gas header. The amount of mixed gas added is controlled by two pressure regulators which keep the gas pressure constant within a few ounces throughout our whole gas system extending from the coke plant to the steel works division.

We achieved therefore a dual purpose with the installation of our gas mixing station:

1. We are able to use all our coke oven gas since we added the 77 in. mill to our mixed gas system, having a stabilized interchangeable gas available as make-up fuel.

2. We stabilized, at the same time, our gas pressure throughout the plant, which meant a considerable improvement in operations at the soaking pits and open hearth furnaces, since we have no gas holder at our plant.

It might be of general interest to give a few operating data of the gas mixing controls:

Since starting up the gas mixing station in May 1938, we have stabilized a wide variation of incoming Btu. gas. Refinery gas Btu. varied from 1650–2140 Btu. per cu. ft. with a gravity fluctuation from .989–1.304. Mixed gas flow varied from 210,000 cu. ft. per hr. down to 10,000 cu. ft. per hr. Straight natural gas was also stabilized for short periods. Variable mixtures of natural gas and refinery gas were also properly stabilized. The controls have given very satisfactory service and required practically no repairs.

It may also be of general interest that it takes us approximately two hours in starting up the controls, and approximately 20 minutes to shut the mixing station down. During approximately 300 operating days we have had three unforeseen shutdowns: one due to a power failure and two because of too low a gas flow in which an automatic safety device switch shut our air blower down. The operation of the mills however was not delayed, since we immediately switched over to straight natural gas.

The many installations of this type of gas mixing equipment have already proven their dependability under various operating conditions delivering a stabilized gas as make-up fuel to be interchangeable with the base fuel of the plant. The question naturally arises as to how this stabilized gas behaves at the consuming end of the line, and if it is really interchangeable at the furnaces. However, before discussing any of our experiences at the furnaces, allow me to discuss briefly the subject from a theoretical point of view. Let us see what we can expect from this stabilized fuel and its behavior in the furnaces.

Gas is stabilized according to its Btu. value and its density. At the furnaces other properties of the gas such as velocity at the burner, flame temperature, volume, specific heat of the products of combustion, radiant energy of the flame, etc., are highly important. We know that gases of different compositions burn with different characteristics within the same furnace. We therefore, cannot expect that the stabilized gas will burn in the same manner as our base fuel in a furnace with a fixed design of burners, ports, furnace outlines and flues. Btu. input, the product of cu. ft. per hr. $\times$ Btu. per cu. ft., will stay constant, but the gas velocity at the burner will change over a considerable range. The burning characteristic is inherent in the gas and relatively little is known yet of the steps of combustion that take place.

We can calculate the final end product of combustion. We can calculate the amount of air necessary for combustion. We know the burning characteristics of the base fuel and the stabilized fuel in our furnace from experience. In comparing the two we will find that the behavior of the two fuels in the same furnace is different. And it is our job to find a solution that will give us proper heating with innumerable variations of mixed gas composition. It is obvious that we must compromise to find a furnace layout that will take care in a reasonable way of all these variables and give us quality and quantity production.

Facing all these facts, it appears to be a very difficult problem indeed. But we only have to remember that all regenerative furnaces also have to be a compromise to a considerable extent: using the ports once as part of the burners and then as part of the flue system.

The solution is possible, since fortunately we have practically the same air requirements for the stabilized gas as for the base gas and also practically the same Btu. input into the furnace with a fixed gas setting. But we must expect a different appearance of the flame within the furnaces and therefore a somewhat different rate of heat transfer.

At the Otis Steel Company we experience very wide variations in the Btu. value of the gas going to our 77 in. mill of from 970–570 Btu. per cu. ft. within a few minutes and vice-versa, due to the heavy fluctuations of the soaking pit demand. Our experience with this mixed gas setup were as follows, bearing in mind that at the Otis Steel Company all these applications have luminous flame burners:

A. *77 in. mill continuous furnaces.*

All burners which had been used on natural gas were adjusted so that there was considerably less primary air mixing in the gas nozzle. It is interesting to note that it was found unnecessary to change the size of the nozzles. Instead, the header pressure on the gas side was raised. It was established that the Btu. input into the furnace did not change for all practical purposes over the wide range from almost straight coke oven gas

to practically straight refinery gas mixture. Nor did air settings have to be changed. However, the appearance of the flame changed considerably and was especially noticeable from a mixture of 50 per cent coke oven gas or more.

The speed of heating (heat transfer) was faster with a straight refinery gas mixture compared to straight natural gas. Natural gas stabilized at approximately 730 Btu. per cu. ft. was very close to the speed of heating with straight coke oven gas, which of course showed the lowest luminosity due to its H_2 content of over 50 per cent. The scale formation on a straight refinery gas mixture was practically the same as on straight natural gas, while natural gas stabilized and coke oven gas gave a lighter scale under otherwise similar operating conditions.

In summarizing our experiences with mixed gas in the continuous furnaces we might say this:

1. Very little, if any, changes have to be made on gas or air settings over a wide range of Btu. per cu. ft. value of the gas.
2. The damper settings become more important when operating on a variable Btu. per cu. ft. of gas. When burning a lighter gravity gas it becomes essential to dampen the furnaces more.
3. We feel that the percentage and composition of the hydrocarbons in conjunction with the gravity of the gas and its products of combustion has a greater influence upon the rate of heat transfer to the steel and scale formation than the mere Btu. content of the gas, when using a luminous flame burner.

B. *Soaking pits.*

At the soaking pits we found the behavior of the straight refinery mixed gas somewhat opposite from what we had experienced at the continuous furnaces. While a straight refinery gas mixture gave us the best results at the 77 in. furnaces, the same mixture performed not as well as straight coke oven gas in the soaking pits. Our pits are of the conventional design with two gas uptakes ahead of each regenerator chamber. Since the pits were designed for straight coke oven gas, no changes were originally made when introducing stabilized gas.

On two pits which are equipped with completely automatic controls, we found that a somewhat higher draft on straight refinery mixed gas helps in burning the gas closer to the port and decreases the formation of smoke. We found no changes on air or gas necessary with varying Btu. per cu. ft. content.

We have tried on some pits to change the port area to accelerate the mixing of gas and air stream and to hasten combustion somewhat. It showed here very clearly again that the manner of firing and the general furnace outlines have a decided bearing upon the flame characteristics.

Straight refinery mixed gas on two one-way fired pits showed a considerable improvement against straight coke oven gas. This experience checked perfectly with what we had found at the continuous furnaces, namely that the gravity of the gas and its products of combustion are very important with overhead firing.

C. *Open hearth.*

Mixed gas is used at the open hearth furnaces at present only for heating up furnaces after a shut down or rebuild, or during such periods when the demand of the 77 in. mill and blooming mill is at times smaller than the supply of our coke oven gas. The gas is then fired through a combination oil and gas burner on one or two furnaces in conjunction with fuel oil. In one instance a furnace was brought up almost to charging temperature with mixed gas firing in a relatively short time, which was previously impracticable. The refinery gas mixture gave a better and more uniform heat than straight coke oven gas, and I believe that it would be superior to even straight natural gas firing. However, the sulphur content of the gas would have to be taken into consideration.

The introduction of stabilized gas and the scientific development and coordination of equipment that controls accurately the mixing of gases according to mathematically predetermined values is, no doubt, a great achievement. Stabilizing equipment opened the market for a new fuel in the steel industry heretofore little known: refinery still gas with its high Btu. value. Modern gas mixing stations, ingeniously designed, made it possible to lay out a gas system within the steel plant with the minimum of waste, by facilitating the most extensive use of all plant fuels. All purchased gaseous fuels can be made interchangeable with the selected base gas of the plant, allowing standardization of equipment with maximum efficiency. In dollars and cents, gas mixing stations have proven to bring a substantial reduction in operating costs.

A. J. FISHER: Mr. Arnold's paper was very interesting to me, particularly the part where higher Btu. gases were stabilized to match lower Btu. standards such as coke oven gas. The use of air for stabilization appears to be risky, inasmuch as any failure of equipment might establish explosive conditions. My suggestion would be to use blast furnace gas instead of air for steel plant mixing stations.

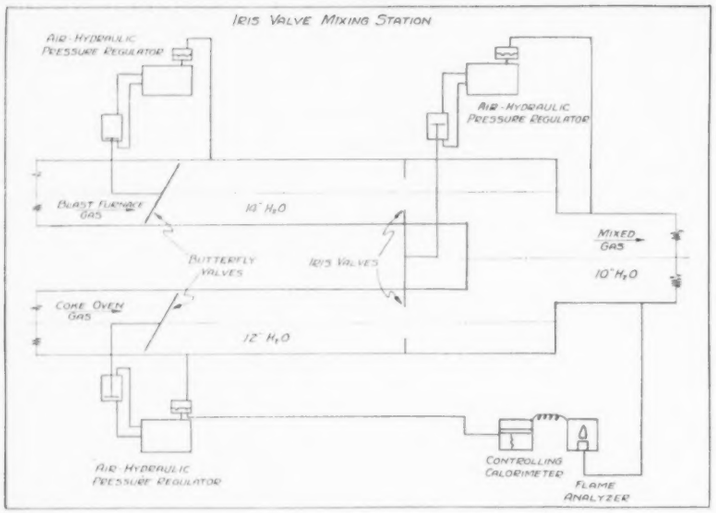
Although a gas may be stabilized for large heating operations where flame character is of minor importance, its alternate use necessarily is limited to operations where a fine flame control is desired, such as radiant tube furnaces, immersion firing with premixed systems, atmosphere gas machines, etc.

The proper steel plant procedure, in my opinion, would be to use the stabilized gas for underfiring of the coke ovens, thus liberating a larger amount of coke oven gas for mill uses. In this case blast furnace gas would be the stabilizing agent.

The required accuracy of a mixing station depends entirely on whether or not holders are used and the size of the holders. Where no holders are used the mixing station must of necessity be very accurate and dependable.

The Maryland plant of the Bethlehem Steel Company is the first plant in this country to use mixed blast furnace and coke oven gas. The first mixing station was hand operated and the mix was determined by the use of a special specific gravity recorder. Later on high and low points were placed on this recorder to operate on electrically driven blast furnace gas butterfly valve.

In 1929 a new mixing station was designed using four butterfly valves operated by hydraulic regulators. A vernier control was attached to the specific gravity recorder by means of an electric eye which changed the



Diagrammatic layout of gas mixing station, using iris valves and three independent pressure regulators.

loading on one of the regulators to give the desired mix. Thus the station was operated volumetrically with specific gravity vernier correction. The degree of control on this station was not particularly good inasmuch as dirt collecting on and around the butterfly valves changed their characteristics; especially on low flows.

This station was redesigned in 1934, replacing two of the butterfly valves with twin iris valves. Special precaution for washing dirt and lubricating these valves was taken into account in the design of these valves. The accompanying figure shows the diagrammatic layout of the mixing station. Note that three pressure regulators are required to operate the station and that these regulators are independent of each other. The pressure regulator operating the butterfly valve that delivers the smallest volume of gas in the mixture should have the vernier control.

In addition to the mill mixing station, we have another identical unit which mixes the same quality of coke oven and blast furnace gas for the city of Baltimore. The quality of the mixed gas varies from 390 to 500 Btu. and is accomplished by means of changing the gas pressures ahead of the iris valves which once set are maintained by the calorimeter vernier control. This gas is in turn hand mixed with refinery oil gas and machine gas to form a mixture of 500 Btu. gas with very close specific gravity and flame characteristic limits. The mixed gas is averaged out in large holders and surprisingly accurate results are obtained.

H. J. VELTEN: Mr. Arnold's paper has covered a subject of very great interest to the majority of fuel engineers in the steel industry. It is based on knowledge and experience from actual installations in steel plants and other industries. Mixed gas is rapidly becoming a more and more important fuel, for economic reasons as well as for the purpose of improving steel products heated and treated in industrial furnaces.

This paper deserves special credit for having brought out for the first time a number of important points in connection with gas mixing, which were not generally known or not published heretofore. One of these points is what has been named the potential heat flow factor, which is the total heat value divided by the square root of the gravity and which is a very important factor in predetermining the heat value of the mixture.

Two or more gases may be mixed not to a constant but a varying heat content, the variations being in accordance with the gravity and so that the burning characteristic of the mixture remains unchanged.

Gas mixture thus obtained can be measured by an orifice whereby the differential pressure is a function of the total heat passing through the orifice or a direct indication of the air required to burn this fuel.

Going a step further: In supplying mixed gas and combustion air to a furnace, the air may be regarded as primary flow and maintained constant. An ordinary volumetric combustion control regulating the fuel input will then not only maintain correct combustion but also a constant heat input into the furnace, the reason for the latter being that the combustion air required per Btu. does not change very greatly for various commercial fuels.

Looking back at the development of gas mixing in steel plants in recent years, it is interesting to see that results have been obtained and success achieved by close cooperation between the plant engineers and the manufacturers of the equipment. The first installation for mixing different fuels was not made so as to give sufficient flexibility and interchangeability of the individual fuel gases. The users complained when discovering that the burning characteristic of the fuel varied and the burners and individual furnace controls had to be re-set frequently to perform satisfactorily.

By tests and calculations it was found that the gases should be mixed according to the variation in heat value of the primary gas in order to obtain the desired flexibility and complete interchangeability of the various components of the mixture.

As we see from Mr. Arnold's paper, very much has been accomplished towards solving the entire problem of preparing and using mixed gas in steel plants but much is left to be done. I am sure that also further successful developments will only be achieved by close cooperation between the plant engineer and the engineer designing the control equipment.

P. F. KINYOUN: I am glad Mr. Fisher brought up about the iris valve. I was going to ask what Mr. Arnold thinks of the advantages or disadvantages of the iris valve as compared to the butterfly valve.

G. M. ARNOLD: In his discussion, Mr. Fisher raises the question of safety in the use of air for stabilizing high Btu. gases and suggests a preference for blast furnace gas for this purpose. In our opinion, air possesses certain advantages in gas stabilization which we believe are not present with the use of blast furnace gas. Undoubtedly gas stabilization with air should include a careful study of the hazards involved in its use. Fortunately, a careful consideration of these hazards show that with modern gas mixing control and with the safe-

guards provided with such control, that the factor of safety is very large so that the likelihood of an explosive mixture or a combustible off-mixture is extremely remote or practically impossible of accomplishment.

In reference to the applications on which stabilized gas can be advantageously used, there are probably some applications where this gas will not satisfy all requirements. As pointed out by Mr. Menges, the use of stabilized gases does require certain compromises, particularly where luminosity, flame temperature, and length of flame change with gas composition. As suggested by Mr. Menges, these problems sometimes offer new problems in combustion control and combustion chamber design where the combustion engineer can by certain changes, tend to reduce the objectionable variables in the more important properties of the gas. It is therefore possible theoretically and practically to make changes which will reduce the number of applications where certain combustion characteristics may produce objectionable effects.

An interesting fact in connection with the maintenance of constant potential heat flow factor H_p and constant heat input is the fact that the momentum of the gas also remains substantially constant. Because of this fact, even on the injector type burner, maintenance of constant H_p and constant heat input will also maintain substantially constant supply of induced air.

Mr. Fisher's proposal of releasing a greater percentage of coke oven gas by substituting the stabilized gas for underfiring of the coke oven, is an excellent one, particularly from the standpoint of coke oven operation. At the same time it might be pointed out that the slower, lazier flames are also frequently desirable in other gas burning equipment. To the best of our knowledge, the first installation where blast furnace gas slightly enriched with coke oven gas to a constant heating value was used for underfiring of coke ovens, was made in June, 1928. This installation included the simplified gas mixing control using a motor operated butterfly valve in the coke oven gas line actuated from a recording calorimeter.

Butterfly valves have been generally preferred for gas mixing control for several reasons. They are less expensive and less complicated than some other types of valves some times used for flow control and therefore are to be preferred for gas mixing where operating conditions are anything but ideal. Butterfly valves for this purpose are carefully designed and manufactured with good operating characteristics over the entire operating range. Because of their construction, butterfly valves are not seriously affected by fouling or corrosion, and consequently do not require any particular maintenance. Furthermore, the corrective impulse from the calorimeter is from an actual measurement of heating value of the finished gas and consequently any errors in proportioning from any cause are continuously compensated for by adjustment of the ratio regulator.

In reference to Mr. Velten's interesting remarks, there is one statement in his discussion which may be subject to misinterpretation. On all gas mixing and gas stabilizing control installations, the primary corrective impulse is from a measurement of gas heating value with secondary adjustment for the effect of changing gravity and combustion air requirements.

A. J. FISHER: I would like to bring up another point. That is the difference in the type of control necessary in the mixing stations, depending on whether the station is ahead of the pumps or behind the pumps. The mixing station that I showed, using pressure regulators, can be situated either before or after the booster pumps. The differential type can not be used ahead of booster pumps because when a pump is put on, the flow is increased, immediately, and this increase in flow decreases the pressure, thus increasing the differential which causes the regulators to close. I cite this condition because, originally, we hooked up a four-valve mixing station differentially and on numerous occasions when we started the pumps the station closed down completely. Anyone who might be anticipating a mixing station ahead of pumps should give this point careful consideration, otherwise you will run into difficulty if you use the differential method.

G. M. ARNOLD: In reference to gas mixing ahead of boosters, many installations of gas mixing control of the pressure differential type have been operating successfully in such a location. In the Great Lakes Steel Corporation plant at Detroit, gas mixing control has been installed immediately ahead of gas boosters and has been operating satisfactorily for many months. In fact, approximately 40 per cent of the differential pressure type of gas mixing control will be found operating ahead of boosters or compressors.

Kenyon DISCUSSION

(Continued from page 34)

controlling your gauge and knowing what safe tensions are possible.

This may be accomplished with the tensiometer. The object of the tensiometer is not to regulate the tension but to indicate what it is, and there are so few mills equipped with tensiometers now, that we haven't a lot of information on relative tensions. After we have more tensiometers in, and can collect our data, we can really take tension into account in making our power study. I hope that every mill that goes in will have tensiometers, because I am firmly convinced that they are becoming more vital all the time.

JAMES FARRINGTON: There is one condition that I believe has not been mentioned, and that is whether you roll dry or use lubricant, and the viscosity of the lubricant. We have at times taken a heavier load on the No. 1 stand than we have on the No. 3. We have changed our lubricant and reversed this condition.

To you gentlemen who are going to buy motors for a new cold mill, I would strongly recommend that you do not use too small a motor on your No. 1 stand, because the roller, and what he is expected to do, and the analysis of the steel may change your practice, and when, as has been brought out before, a different roller comes on he will change the mill setup very materially. Do not neglect to have sufficient horsepower in your first stand.

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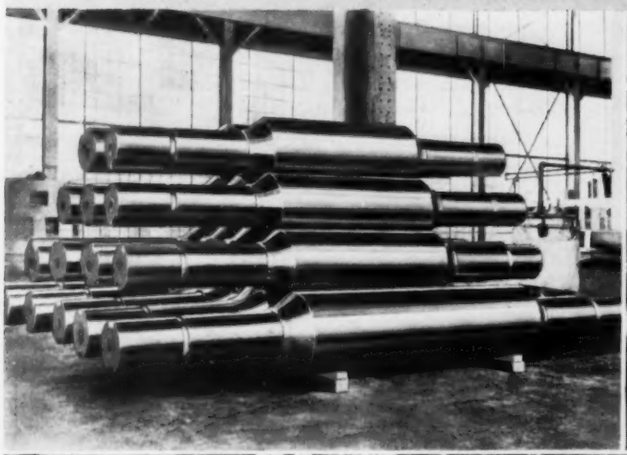
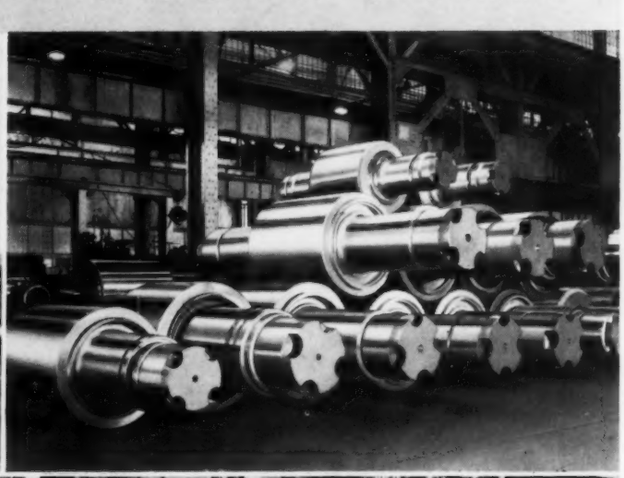
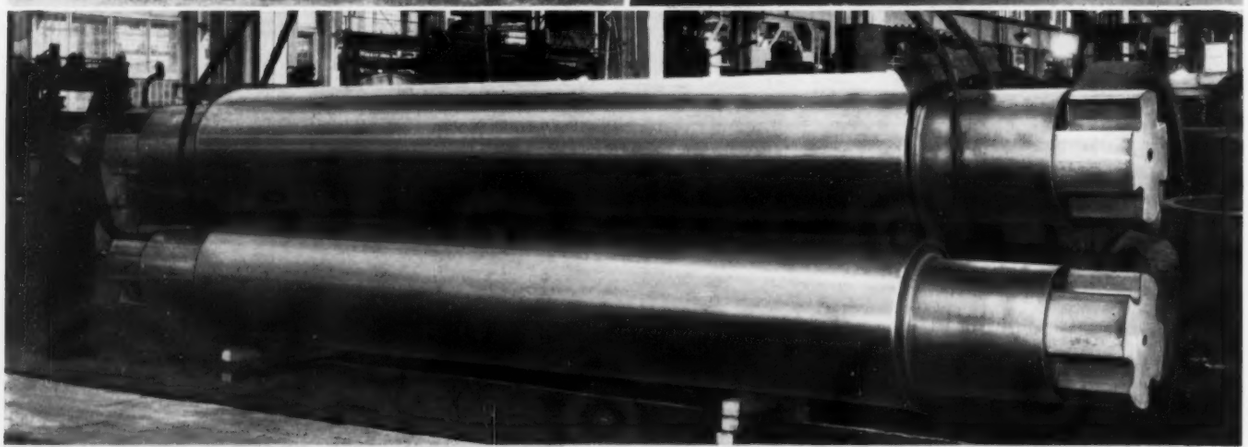


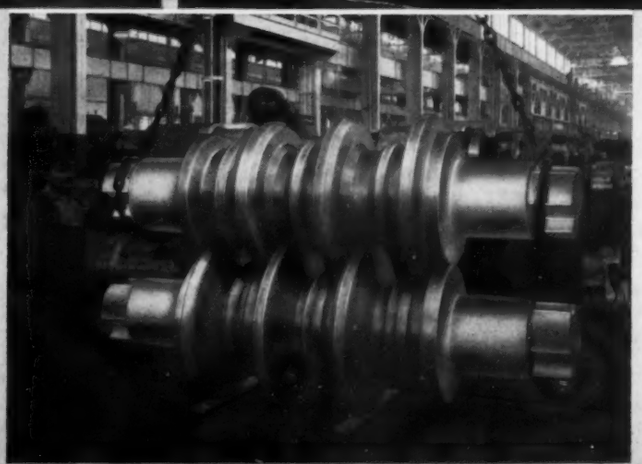




Plain Chill
Molybdenum Chill
Sand Grain
Mesta Nickel Chill
Mesta Nickel Grain
Mesta Hardened Chill
Mesta Hardened Grain

Carbon and Alloy Steel
"Mesta Special" Alloy Steel
Forged Hardened Steel

Heat Treated Special Alloy Steel Backing-Up Rolls



MESTA MACHINE COMPANY · PITTSBURGH, PA.

Continuous STAINLESS STEEL Production at Republic Steel Corporation

Iron and Steel Engineer, May, 1940

Continuous Production Methods for STAINLESS STEEL

By T. J. ESS with personnel photographs by J. R. SCOTT

▲ STAINLESS STEEL, as the steels containing high percentages of chromium and chromium with nickel are generally termed, has well outgrown the novelty stage, and is now one of the fastest growing groups of alloys being produced, the 1939 production for the United States reaching the figure of 179,620 tons. Of German and English origin, stainless steel was discovered about 28 years ago, but there was no active commercial development until about 1923. The many properties of these alloys as related to corrosion and heat resistance, plus their adaptability to almost every type of forming and fabrication process, have led to their use as automobile trim, in streamlined railroad construction, in food processing or other industries where no chemical contamination can be tolerated, in architectural applications, aircraft construction, cooking utensils and equipment, and a host of other miscellaneous applications. The recent development of the coloring of this material may lead to still wider use.

Under the trade name "Enduro," the Republic Steel Corporation produces a wide variety of types to meet trade requirements, with chromium ranging 10 to 30 per cent and nickel from 2 to 36 per cent, in addition to other alloying elements such as titanium, columbium, molybdenum, etc.

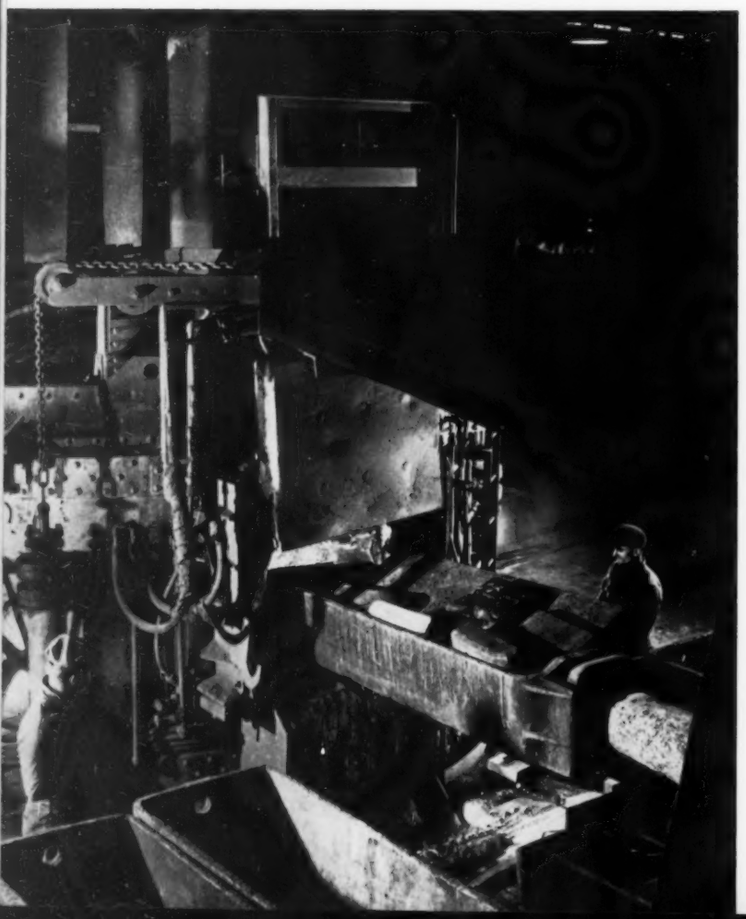
To meet the increasing demands for these materials, Republic has greatly expanded and improved its stainless producing facilities. The equipment now in use is essentially the same as that employed for the production of the common grades of steel, the practice, while differing somewhat due to certain characteristics of the alloys, is also in substantial agreement, and the modern continuous methods for flat-rolled production are successfully applied to this material.

All of Republic's stainless is made in basic electric furnaces located in the Canton plant, and giving a monthly capacity totaling 17,300 tons per month. There are one 25-ton, three 15-ton and one 6-ton arc furnaces, in addition to one 6-ton low frequency induction furnace, in the electric furnace department of this plant, and, recently installed, one 50-ton and one 25-ton arc furnace located in the open hearth department. In addition to the stainless types, these furnaces produce special carbon and alloy steels of all analyses. General characteristics of these furnaces are as follows:

Furnace capacity, tons	Transformer rating, kva.	Hearth area, sq. ft.	Electrode diameter, in.	Secondary voltage
6	2,800	40	12	110–180
15	4,500	64	14	110–220
25	10,000	100	18	115–240
50	12,000	165	18	107–275

The transformers on the newer furnaces are provided with motor-operated tap changers mounted upon the transformer case, but operating in a separate oil filled compartment. A wide choice of voltages is thus offered to the operator. For example, the 12,000 kva. unit applied to the 50 ton furnace offers 275, 260, 245, 230

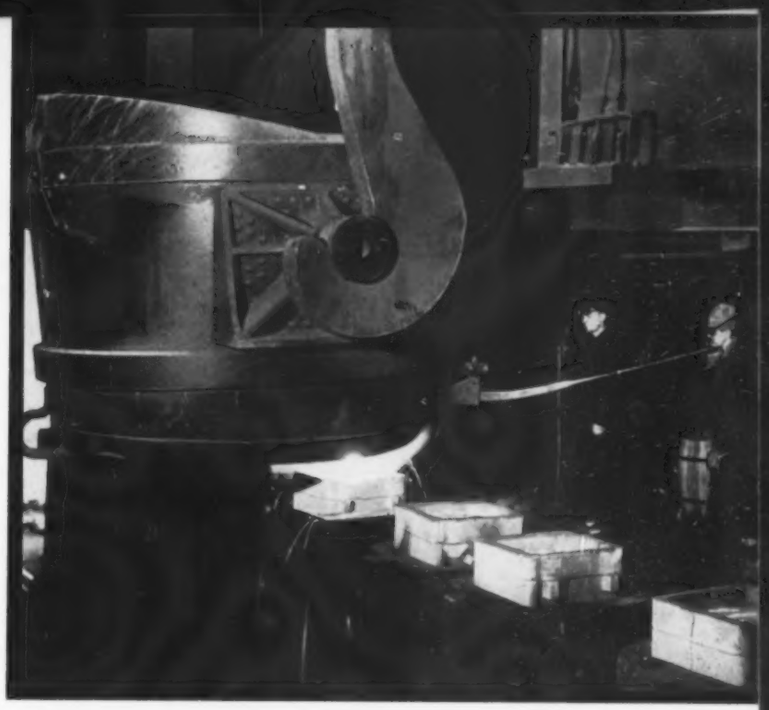
In the production of stainless, electric furnaces receive a carefully prepared charge of material based on an established practice depending on the type of product.



and 215 volts with delta connections and full capacity, 200 and 185 volts with delta connections and reduced capacity, and 159 and 107 volts with Y-connections.

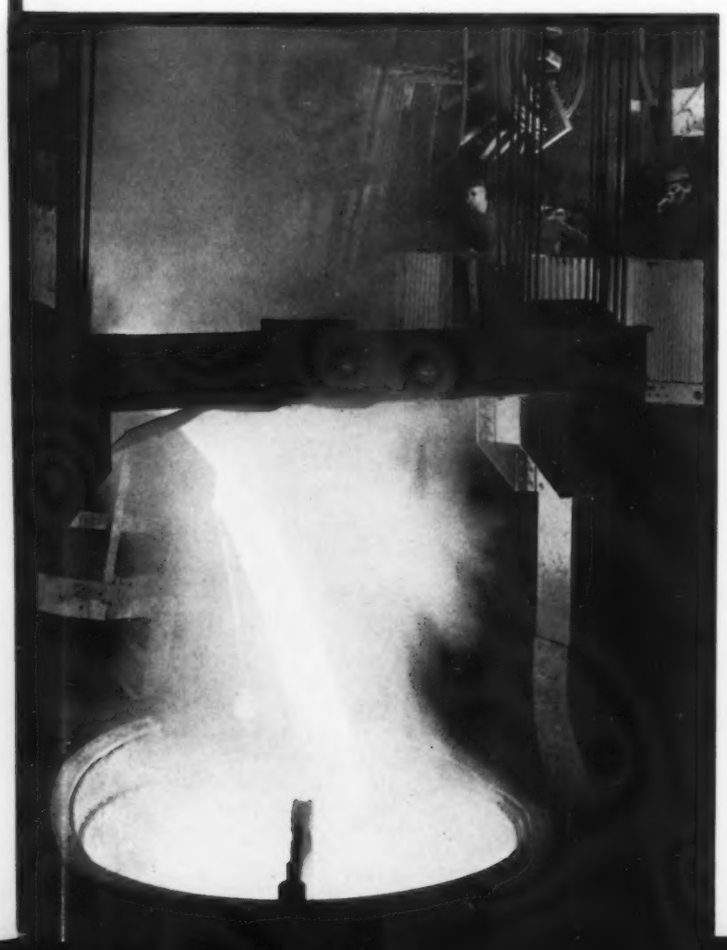
The transformers are all oil-immersed, water-cooled, and operate on a primary voltage of 22,000. Automatic electrode control is effected through an unusual system of special design, developed in this plant.

A special hearth construction, also developed in this plant, is used in these furnaces. The sub-hearth consists of a flat course of firebrick against the shell, on top of which are laid several courses of magnesite brick extending up the side wall to just above the slag line. Sidewalls and roof are lined with silica brick. The working hearth is composed of a mix made up of 80 per cent of graded periclase grain and 20 per cent of finely ground Austrian magnesite, to which is added a binder of liquid silicate of soda. The periclase is a magnesium oxide grain that has been burned at high temperature to give approximately the properties of fused magnesium oxide. The mix is graded 20 per cent ½–¼ in. mesh periclase grains, 90 per cent MgO; 20 per cent ¼–⅛ in. mesh periclase grains, 90 per cent MgO; 40 per cent ⅛ in. mesh to fines periclase grains, 90 per cent MgO; and 20 per cent 1/16 in. to fines dead-burned Austrian magnesite, 83 per cent MgO. Somewhat over 5 quarts of liquid silicate of soda per 100 lb. of mix are required to attain the desired plasticity for ramming. The mix is rammed in layers of 2 or 3 in. at a time until the hearth is up to the required thickness and contour. Drying for 24 hr. with a wood fire is followed by application of the arc, and the furnace is brought up rapidly and held at a temperature just below the fusion point of the silica brick in the sidewalls and roof. After 24 hr. more the bottom will be sintered to a depth of 3 to 5 in. and ready for operation.



Stainless is cast into prepared hot-topped ingots ranging 4500–9500 lb. in weight, and varying in size in accordance with the slab to be produced.

Republic's stainless is produced, in a wide variety of types, in basic electric furnaces with a total capacity of 17,300 tons per month.



In the open hearth building, the electric furnaces are served by the previously existing charging, tapping and pouring facilities. In the electric furnace department, scrap is brought to the furnaces by narrow gauge railroad. Two charging cranes are available for charging the furnaces, and three ladle cranes furnish adequate pouring facilities.

The practice employed in the production of the stainless alloys in these furnaces has been discussed at length in the paper "American Electric Furnace Practice," by W. M. Farnsworth and E. R. Johnson, *Journal of the Iron and Steel Institute*, 1938, No. II, page 289.

The steel is poured into hot-topped ingots ranging 4500–9500 lb. each, the sizes generally running 14 in. x 24 in., 16 in. x 26 in., 16 in. x 32 in., 20 in. x 23 in., and 20 in. rounds, depending on the slab sizes to be rolled. The molds are previously coated with a mixture of aluminum powder, shellac and alcohol. After solidification, the ingots are loosened in the molds and are moved on to the soaking pits or forge shop. Most of the various stainless types may be rolled into slabs with the exception of about three types, which are forged.

Heating facilities at the blooming mill are composed of one block of four holes of one-way fired pits and seven blocks, each of four holes, of reversing regenerative pits, all fired with producer gas. There is also a four-hole row of warming pits for preheating cold ingots, burning coke oven gas. Ingots are preferably charged hot into the pits, and, if charged cold are first placed in the warming pits or in the regular pits which have first been chilled. The low conductivity of the stainless

Slabs are carefully inspected and conditioned to remove all surface defects before subsequent rolling. Small slabs as shown here are used for sheet production.

alloys requires a long, slow heating cycle in comparison with the more common steels, with an added soaking period of 3 to 6 hours, depending on ingot size. Rolling temperatures average 2200–2250 degrees F.

The ingots are rolled in a blooming mill unit consisting of two 2-high reversing stands, the first a 35 in. mill and the second a 34 in. mill. Rolling practice on stainless varies from the general practice mainly in the smaller reductions taken in each pass. From 30 to 50 per cent more passes are necessary for the same reduction on stainless, and the mill production is 20–25 per cent lower than the general average. Slabs for strip production are rolled in sizes ranging 9–27 in. in width, 2⅝–3⅛ in. in thickness, and 8 ft. 6 in. to 17 ft. in length. For sheet production, lengths of 16–47 in. are used.

The slabs next proceed through the billet sheds where they are carefully inspected and conditioned to remove all surface defects. The grinding process is employed, using a resin-bonded wheel of about 12 grit in swing frame grinders. An average of about 4.5 man-hours per ton is required for this conditioning process.

Stainless sheet and light plate production is carried out in a train of hot mills composed of two jobbing units and two conventional hand mills. Each jobbing unit consists of a roughing and a finishing stand, with a slab furnace and a reheat furnace. The hand mills are fed from two four-door batch type heating furnaces. Finishing equipment includes a normalizing furnace, a rocker-type batch pickler, a cluster type cold mill, and a conventional cold hand mill. Sheets which are to receive still further surface treatment are then sent to the polishing and grinding department at the Massillon plant, where there are thirteen roll type machines and two belt type machines, in addition to a heavy duty automatic sheet grinder. By the proper selection of grinding rolls, brushes, and polishing rolls, any desired finish may be obtained on the sheets up to a perfect mirror finish. Sheets up to 68 in. wide x 24 ft. long may be thus treated.

The conditioned stainless slabs are hot rolled into strip on the No. 1 hot strip mill at the company's Warren plant. This mill was one of the pioneer strip mills of the country, built in 1917, and has been subsequently rebuilt and widened until it is now a 42 in. mill conforming to a great extent with the conventional layout of the modern strip mill. The mill at present has a nominal monthly capacity of 40,000 tons, and an average rolling rate of about 66 tons per hour. The stainless alloys, however, form only about 10 per cent or less of the total tonnage of this mill, and on this product, the rolling rate is only about 25 tons per mill hour.

From the storage, slabs are brought to the heating furnaces by overhead crane, and are deposited on magazine elevator feeders of special design, operated hydraulically. There are two feeders on each furnace. Two electrically operated rack-type pushers are provided on each furnace. It is essential that the stainless slabs entering the furnace be clean and free from any foreign matter.

There are three triple-fired continuous zone controlled slab heating furnaces, each rated at a capacity of 35 gross tons of steel per hour. Hearth dimensions are 18 ft. 6 in. width x 49 ft. 6 in. length, about 12 ft. of the latter being a solid hearth soaking zone. The furnaces are fired with natural gas or, when available, mixed coke oven and blast furnace gas. Six burners serve the

F. E. FLYNN, *District Manager*
Warren District

C. W. MEYERS, *District Manager*
Central District

main top heating zone, five serve the bottom heating zone, and eight the soaking zone. These burners, of the luminous flame type, give a total capacity of about 75 million Btu. per furnace hour, and normally operate at about half of that rate.

Combustion air, supplied from one fan for each furnace, is preheated to about 500 degrees F. in the recuperator with which each furnace is provided. The furnaces are metal cased, with 4½ in. of insulation on the sidewalls and 2½ in. on the flat suspended roofs. Fuel-air ratio controls are supplied for each firing zone, while furnace pressure control and temperature control are provided in the soaking zones.

Furnace production, which averages about 23 tons per furnace hour on plain carbon steel, is materially reduced when heating stainless steels. For this material, the average is about 8 tons per furnace hour, indicating a heating cycle of three times that of plain steel. Fuel consumption while heating stainless averages about 3,500,000 Btu. per ton, which is about twice the general mill average.

From the furnaces the slabs pass over a mill table about 130 ft. long leading to the hot mill, the first unit of which is a 2-high, 24 x 42 in. scalebreaker, driven by a 1200 hp., 2300 volt, 585 rpm. induction motor. The four stands forming the remainder of the roughing train are duplicate 2-high, 25 x 42 in. stands, all driven through gearing by a single 3500 hp., 2300 volt, 315–405 rpm. induction motor operating from a Scherbius motor-generator set. Three separate vertical edging stands are incorporated in the roughing train, the first driven by a 300 hp. motor, and each of the last two by a 100 hp. motor, all of 250 volts d-c., 400–800 rpm. The spacing of the roughing train units does not conform to the conventional plan of the more recent mills, but is as follows: scale breaker to No. 1 edger, 34 ft. 5 in.; No. 1 edger to No. 1 rougher, 8 ft. 7¾ in.; No. 1 rougher to No. 2 rougher, 13 ft. 3 in.; No. 2 rougher to No. 2 edger, 8 ft. 7¾ in.; No. 2 edger to No. 3 rougher, 23 ft. 4¼ in.; No. 3 rougher to No. 4 rougher, 32 ft.; No. 4 rougher to No. 3 edger, 8 ft. 7¾ in.

No broadside rolling is done in this mill, hence the

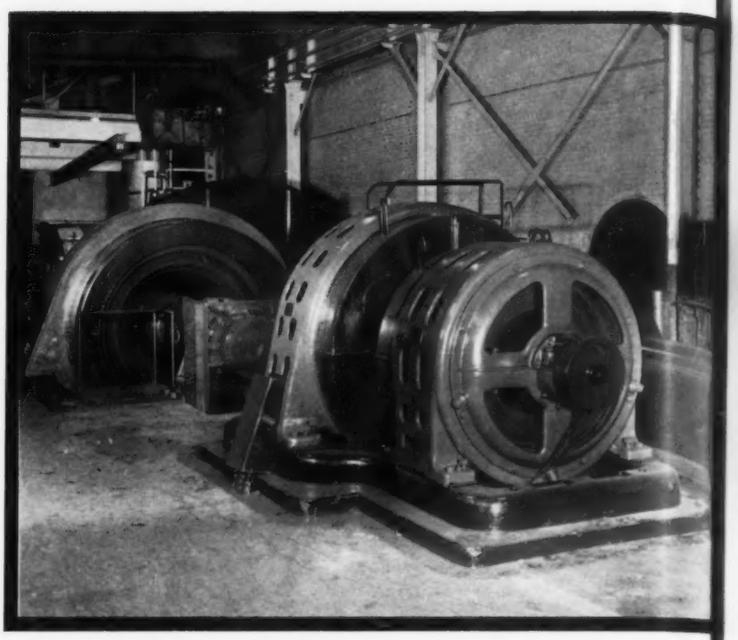
The roughing train of the Warren hot strip mill consists of a scalebreaker, four two-high 25 in. x 42 in. roughing stands, and three separate vertical edgers.

usual turntables, pusher and slab squeezer are not installed.

A delay table 130 ft. long separates the roughing train from the finishing train, which is composed of six 4-high stands, 16½ and 32 in. x 42 in., spaced 20 ft. apart with the exception of stands No. 7 and 8, which are on 23 ft. center lines. The first two stands are driven through gearing by a single 5000 hp., 2300 volt, 270–450 rpm. induction motor. The third finisher is driven by a 2500 hp., 600 volt, 225–450 rpm., d-c. motor, while each of the last three is driven by a 2000 hp., 2300 volt, 270–450 rpm. induction motor. A 42 in. upcut crop shear is installed in the delay table.

Gear ratios, mill speeds, etc., are as follows:

	Motor rpm.	Gear ratio	Roll rpm.	Roll speed, ft. per min.
Scalebreaker	585	19.3	30.31	190.3
Edger	400/800	70.5	5.68/11.36	
No. 1 rougher	315/405	24.5	12.86/16.53	84.13/180.14
No. 2 rougher	315/405	15.4	20.43/26.27	133.65/171.86
Edger	400/800	31.0	12.9/25.8	
No. 3 rougher	315/405	11.0	28.6/36.8	187.5/241.1
No. 4 rougher	315/405	8.4	37.49/48.2	245.26/315.32
Edger	400/800	17.15	23.33/46.66	
No. 5 finisher	270/450	8.27	32.65/54.42	141.05/235.09
No. 6 finisher	270/450	5.19	52.04/86.73	224.81/374.67
No. 7 finisher	225/450	2.58	83.95/167.9	351.58/703.16
No. 8 finisher	270/450	2.56	105.3/175.5	454.9/758.16
No. 9 finisher	270/450	2.04	132.3/220.5	571.54/952.56
No. 10 finisher	270/450	1.775	152/253.35	656.64/1094.47

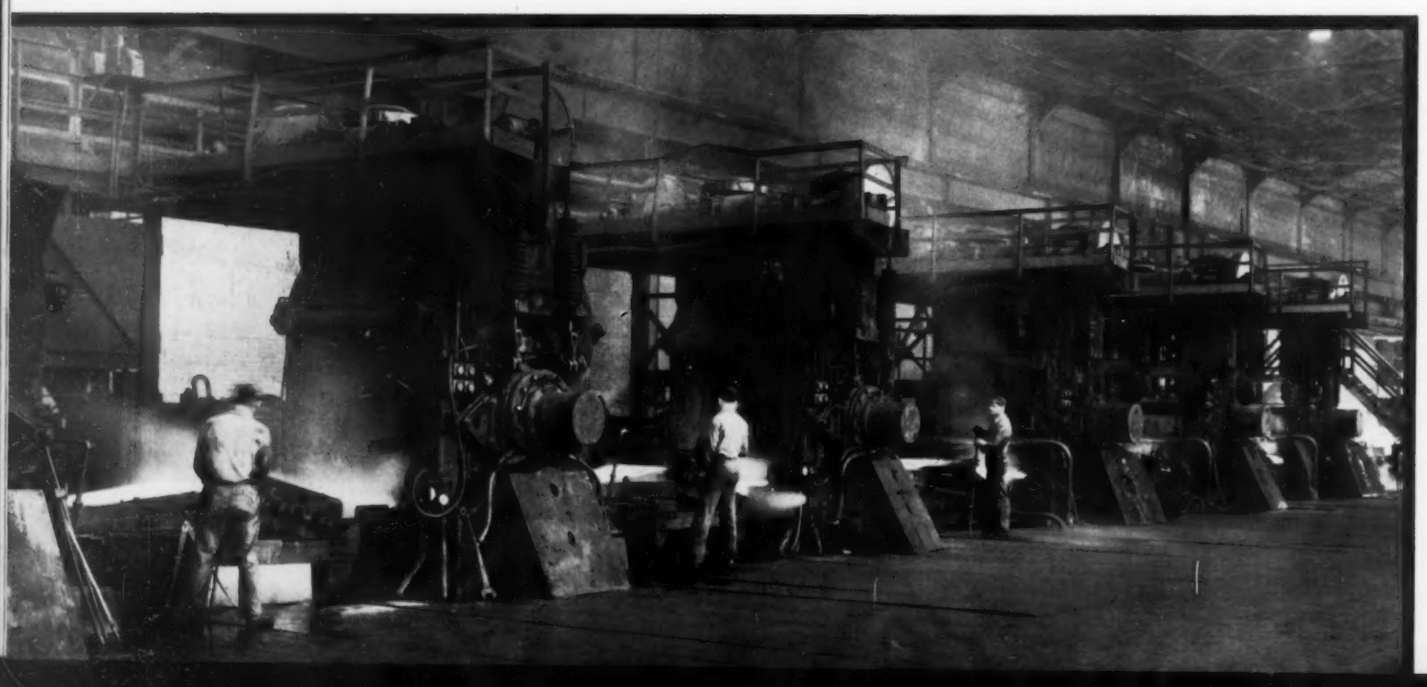


A single 3500 hp., 2300 volt induction motor, operating under a Scherbius control system, drives the entire roughing train through suitable gearing.

The 2-high stands operate in oil film bearings, while 4-high stands are equipped with roller bearings on both work rolls and back-up rolls. Screwdowns on the 2-high stands comprising the roughing train are operated manually through large hand wheels, while the 4-high finishing mills are each provided with motor-driven screwdowns, the two motors being joined through a magnetic clutch.

Pneumatically operated loopers, under manual control, are installed between successive finishing stands. Descaling sprays are placed at the exit of the scalebreaker and of No. 3, 5 and 6 mill stands, and are supplied with water at 1200 lb. pressure by a centrifugal pump of 1200 gal. per min. capacity. About 650 gal. of water is thus used per ton of plain steel rolled. On stainless, this water use is reduced to a very small amount or eliminated entirely, depending on the type of material being rolled. Steam jet blowers are also placed on both sides of No. 1 stand and between No. 2 and 3 stands.

From the finishing train, the runout table proceeds for about 280 ft. to three coilers placed in tandem at the end of the runout. They are designed to form



The finishing train of the hot strip mill is composed of six four-high stands, 16½ in. and 32 in. x 42 in. with maximum delivery speed of 1095 ft. per min.

material 36 in. wide into coils of 42 in. maximum outside diameter and each is driven by a 75 hp. variable speed d-c. motor. The runout table is composed of 87 individually driven rollers, each driven by a 3 hp. variable frequency motor, and operates in a speed range of 630–1260 ft. per min. On each side of the runout table there is a parallel table, to which strip is moved over hot beds 165 ft. long. Each of these parallel tables, driven through line shafts, totals about 250 ft. in length, and contains a shear, a piling table, and a scale table. The material in cut lengths is removed by overhead crane. Coils from the hot coilers are carried by a conveyor to the hot strip finishing department. Coiling temperatures are very important in the production of stainless steel.

The hot mill is housed in a building 1240 ft. long x 100 ft. wide, and is served by three cranes, one of 10 ton and two of 15 ton capacity.

Roughing stand roll necks are lubricated from an automatic circulating oil system, of 800 gal. storage capacity and 10 gal. per min. circulating capacity. Two similar systems, of 7500 gal. and 500 gal. storage capacity, respectively, and both of 30 gal. per min. circulating capacity, supply lubrication to the mill drives and pinions. Back-up and work roll necks, table rollers, looper rolls, and runout table rollers are all grease lubricated, from manually operated systems.

In hot rolling stainless strip, regular rolling speeds are used unless it is necessary to slow down in order to obtain the proper finishing temperature. The schedule of reductions in the various passes usually shows drafts averaging under 28 per cent reduction to area per pass, with a maximum of about 37 per cent and a minimum of 10 per cent. Rolls must be smooth and in good condition, and every precaution is used to prevent scratching as the strip progresses through the mill. The straight chrome alloys are produced in widths ranging 9–26 in., and in gauges down to .109 in. Chrome-nickel types are produced in 9–23 in. widths down to .125 in., and in 26 in. widths down to .156 in. It is planned to extend these limits, going to a maximum width of 30 in. and hot rolling all grades down to .109 in.

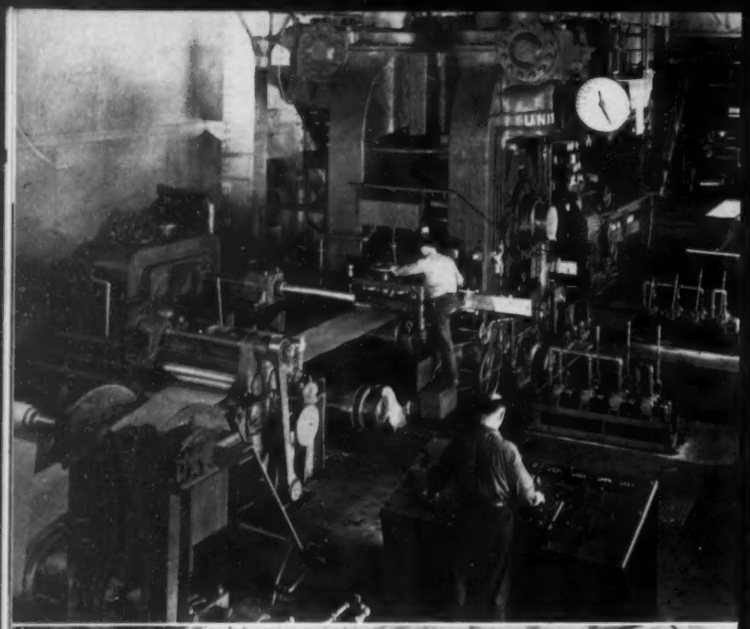
G. W. PUTNAM, *Assistant District Manager*
Central District

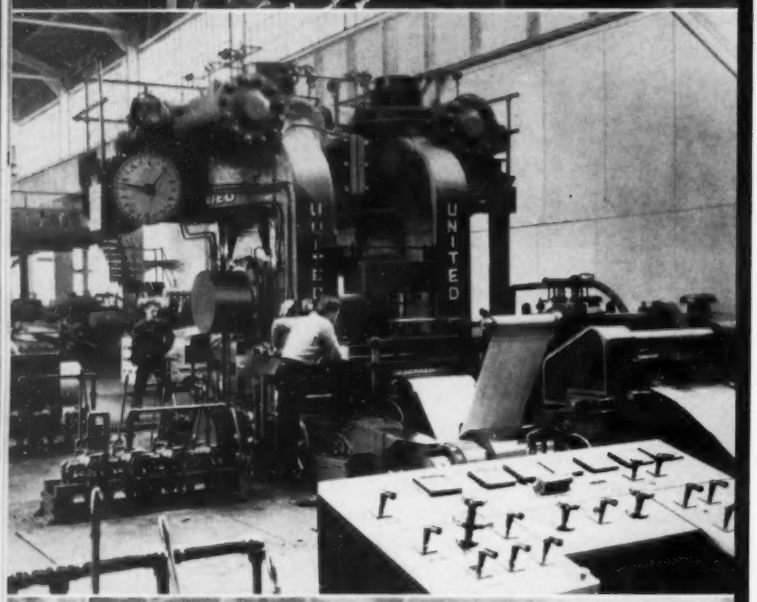
J. H. GRAFT, *Assistant District Manager*
Warren District

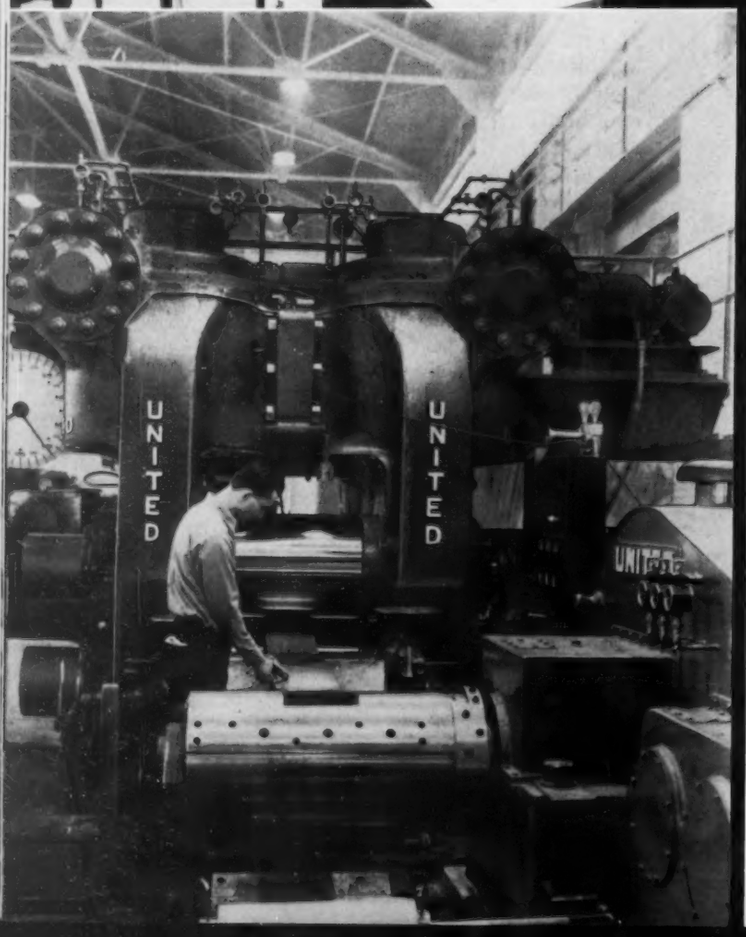
The hot mill motor room is 400 ft. long x 42 ft. 5 in. wide, and contains one 15 ton crane. A lean-to adds about 11 ft. to the available width of this room. Here are housed the main drive motors and reduction gears of the hot mill, together with the necessary electrical control equipment. The variable speed a-c. motors are controlled by the Scherbius system, using five speed regulating sets, three composed of 480 kva., 230 volt generator and a 475 hp., 2300 volt, 514 rpm. motor, one of a 360 kva., 190 volt generator and a 370 hp. 2300 volt, 514 rpm. motor, and one of two 480 kva., 230 volt generator and a 1175 hp. 2300 volt, 514 rpm. motor. The single 2500 hp. d-c. drive on No. 7 finishing stand has been recently installed, this mill being formerly driven through gearing from the 5000 hp. motor which drives No. 5 and 6 stands. Power for this d-c. drive is furnished from a motor-generator set composed of a 2000 kw., 600 volt d-c. generator driven by a 2800 hp., 2300 volt synchronous motor.

The individual drive motors in the runout table receive their power from a variable frequency set composed of a 500 kva., 30–60 cycle alternator driven by a 375 hp., 480–960 rpm., 250 volt d-c. motor.

Auxiliary d-c. power is supplied from a 750 kw. 250







(Left, top) General view of 34 in. reversing cold mill, designed for the complete rolling of all material over 24 in. wide, and breakdown rolling of material over 16 in. wide.

(Left, center) The 28 in. reversing mill is planned for the intermediate and finish rolling of stainless strip up to 24 in. wide.

(Left, bottom) Temper rolling for all widths up to 30 in. is performed in a two-high 26 in. x 34 in. non-reversing mill, equipped with separate tension rolls on the exit side.

(Above) General view of 34 in. mill motor room, showing the 1000 hp., main drive motor, auxiliary control set, circuit breakers, and control panels.

volt motor-generator set, and a tie-line connecting to units located elsewhere in the plant.

The main electrical units are cooled by forced up-draft ventilation, supplied from two fans, of 100,000 cu. ft. per min. each. No air coolers are installed, fresh air being drawn through filters and passed through the units, except in winter, when partial recirculation is used.

The hot mill contains rotating electrical machinery as follows:

	Number	*Total hp.*
Motors	246	25,060
Generators	9	7,680
Total hot mill	255	32,740

Accurate segregation of the power load, etc., of this mill is impractical due to the fact that it is so closely tied in with other mills and departments in the plant. Power for the entire plant is partially generated, partially purchased.

The greater part of the product from this hot mill consists of the common grades of flat rolled product, about half going to hot rolled finishing, 30 per cent to tinplate, and 10 per cent to full finished product. Some electric strip, containing 2½ to 4 per cent silicon is also rolled, in addition to the stainless alloys. All of this material except the stainless is finished in the Warren district. To meet these requirements three continuous pickling lines are installed, totaling a monthly

capacity of about 20,000 tons. Cold rolling equipment includes a 4-high, 10¼ and 32 in. x 38 in. reversing mill, a 4-high, 18 and 49 in. x 42 in. reversing mill, a 4-high, 14 and 32 in. x 42 in. mill, a 4-high, 10 and 29 in. x 20 in. mill, a three-stand, a 4-high 14 and 32 in. x 42 in. tandem mill, a 2-high, 20 in. x 30 in. mill, a 2-high, 20 in. x 42 in. mill, two 2-high 12 in. x 16 in. mills, a 2-high, 16 in. x 26 in. mill, and a four-stand 2-high, 16 in. x 20 in. tandem mill, in addition to other small mills. Thirty in-and-out box annealing furnaces, two normalizing furnaces, two batch type picklers and miscellaneous cutting equipment complete the finishing facilities in the Warren plant.

Tinplate is produced from coils rolled on this hot mill in a modern cold reduction plant at Niles, six miles away. Here are installed a continuous pickling line, a four stand, 4-high, 18 and 49 in. x 42 in. tandem mill, three electrolytic cleaning lines, sixteen in-and-out box annealing furnaces, a white pickler, and eight tinning lines.

The expansion program recently completed concentrates all of the stainless cold reduction and finishing at Republic's Massillon plant, with a monthly capacity of 1200 net tons. Previously, a capacity of 575 tons per month was available, 325 tons of which was at the Massillon plant and 250 tons at the Warren plant. The new set-up gives the advantage of unified production, as well as increasing the capacity.

The new cold mills installed at Massillon include three four high reversing units and one two high non-reversing temper mill. There is a 15 and 42 in. x 34 in. unit for the complete rolling of all material over 24 in. wide, and for breakdown rolling of material over 16 in. wide. This unit is designed to take centerless coils 20 in. inside diameter, 44½ in. maximum outside diameter, of material up to .3 in. thick and 30 in. wide. By sling and crane coils are placed in a coil box with cradle rolls and disc type rotating side guards, or in an expanding mandrel type pay-off reel with friction drag brake. An air-operated coil opening device aids in entering the leading

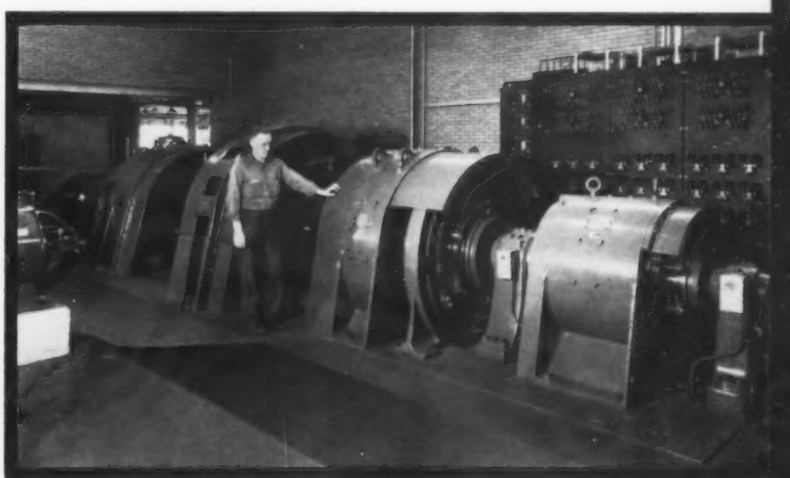
W. M. FARNSWORTH, *Plant Superintendent*
Canton Works

end of the coil into the mill. The strip is fed into the mill through a five-roll feeding device which is driven by a 30 hp., 400–1200 rpm. shunt motor.

The mill housing is of cast steel, with closed top design. Each housing post has a cross-sectional area of 504 sq. in. Back-up rolls run in four-row type roller bearings, 23 in. x 35½ in. x 21¼ in., and rated at a capacity of 545,760 lb. at 500 rpm. on a 15,000 hr. life basis. These bearings will provide for a pressure of 117,000 lb. per in. width of strip at the average conditions of 22½ in. strip width and 262 ft. per min. strip speed. Back-up roll chocks are of cast steel, complete with retainers, lubricant seals, and patented latch type retaining clamps for properly locating the chocks in the

J. H. KENNEDY, *Superintendent, Electric Furnaces*
Canton Works

View of 28 in. mill motor room, showing combination motor-generator set which supplies power to both the 28 in. and the 20 in. mills.



R. C. GINTERT, *Superintendent, Hot Strip Mill*
Warren Works

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R. S. LYNCH, *Superintendent, Stainless Division*
Central District

housings. Leg extensions of the back-up roll chocks are provided with removable end extensions which may be taken out when using work rolls of the minimum (10 in.) diameter. Forged alloy steel work rolls, of 90–100 scleroscope hardness, operate in four-row roller bearings, 7 in. x 11¼ in. x 8¾ in. These bearings are mounted in cast steel chocks, also complete with retainers, lubricant seals and latch type clamps. The bottom back-up and work roll chocks are equipped with cylinders for balancing their respective top rolls.

This mill is driven at 43.3–86.5 rpm. through a gear reduction set of 9.25:1 ratio and a separate set of 14½ in. pinions by a 1000 hp., 400–800 rpm., 600 volt, d-c. motor, giving a strip speed of 175–350 ft. per min. with maximum size rolls. The gear set is a single reduction unit, with forged alloy steel pinion and special cast steel gear, both with double helical cut teeth. A gear type flexible coupling is provided between the motor and gear set, and between the gear set and pinions. Universal spindles and couplings are used, with spring balanced type spindle carrier.

The screwdown is of double reduction worm gear type, driven by two 25 hp. 650 rpm., 230 volt d-c. motors. The screws are 14 in. in diameter, with a pitch of .4 in. A reduction of 1025:1 is afforded between motor and screw. The screws may be operated separately or, through an 18 in. magnetic clutch, in unison.

On each side of the mill is located a 20 in. collapsible reel, driven through a 13.5:1 ratio gear reduction by a 250 hp., 250–1000 rpm., 600 volt d-c. motor. Also on each side of the mill are wedge type entry guides with manually adjusted side guides supported on rest bars, strip wipers, 16 in. hollow type deflector rolls mounted in roller bearings, and electro-limit gauges. A three-roll up-coiler with tailing device and hydraulic kick-off is also placed on the delivery side of the mill for use on break-down passes. This unit is driven by a 75–100 hp., 300–1200 rpm. shunt motor.

For the intermediate and finish rolling of strip up to 24 in. wide, a 10 in. and 36 in. x 28 in. four-high reversing mill has been installed. This mill takes coils 20 in. inside diameter, 44½ in. maximum outside diameter, of material up to .105 in. thick and 24 in. wide. This unit is similar in general design to the 34 in. mill previously discussed. The housing posts are each of 400 sq. in. sectional area. Back-up rolls operate in four-row 20 in. x 30 in. x 20¾ in. roller bearings designed for 410,400 lb. at 500 rpm. on a 15,000 hr. life basis, and affording a mill pressure of 148,000 lb. per in. of strip width under the average conditions of 13½ in. strip width and 262 ft. per min. strip speed. Work roll bearings are 5⅛ in. x 8½ in. x 4⅞ in. in size. Work rolls and back-up rolls are all of forged alloy steel.

A roll speed of 91.5–183 rpm., or 250–500 ft. per min., is attained through a 2.62:1 gear ratio, from the 800 hp., 240–480 rpm., 600 volt d-c. motor. Ten inch pinions are normally installed, but a spare set of 6 in. pinions may be substituted if it is desired to go to 6 in. work rolls in order to roll lighter gauges. Mill screws are 12 in. in diameter, with .4 in. pitch, and are driven by two 15 hp., 800 rpm., 230 volt d-c. motors, joined by a 14 in. magnetic clutch. A 20 in. reel is placed on each side of the stand, driven by a 200 hp., 250–1000 rpm., 600 volt d-c. motor through a 9.42:1 reduction. A three-roll

J. D. DONOVAN, *Superintendent of Maintenance*
Massillon Works

pinch roll, driven by a 20 hp., 400–1200 rpm., shunt motor, feeds the strip into the mill, and 12 in. deflector rolls, automatic gaugers, guides, etc., are provided. A hydraulically operated lift and traverse is used for charging coils to the mill.

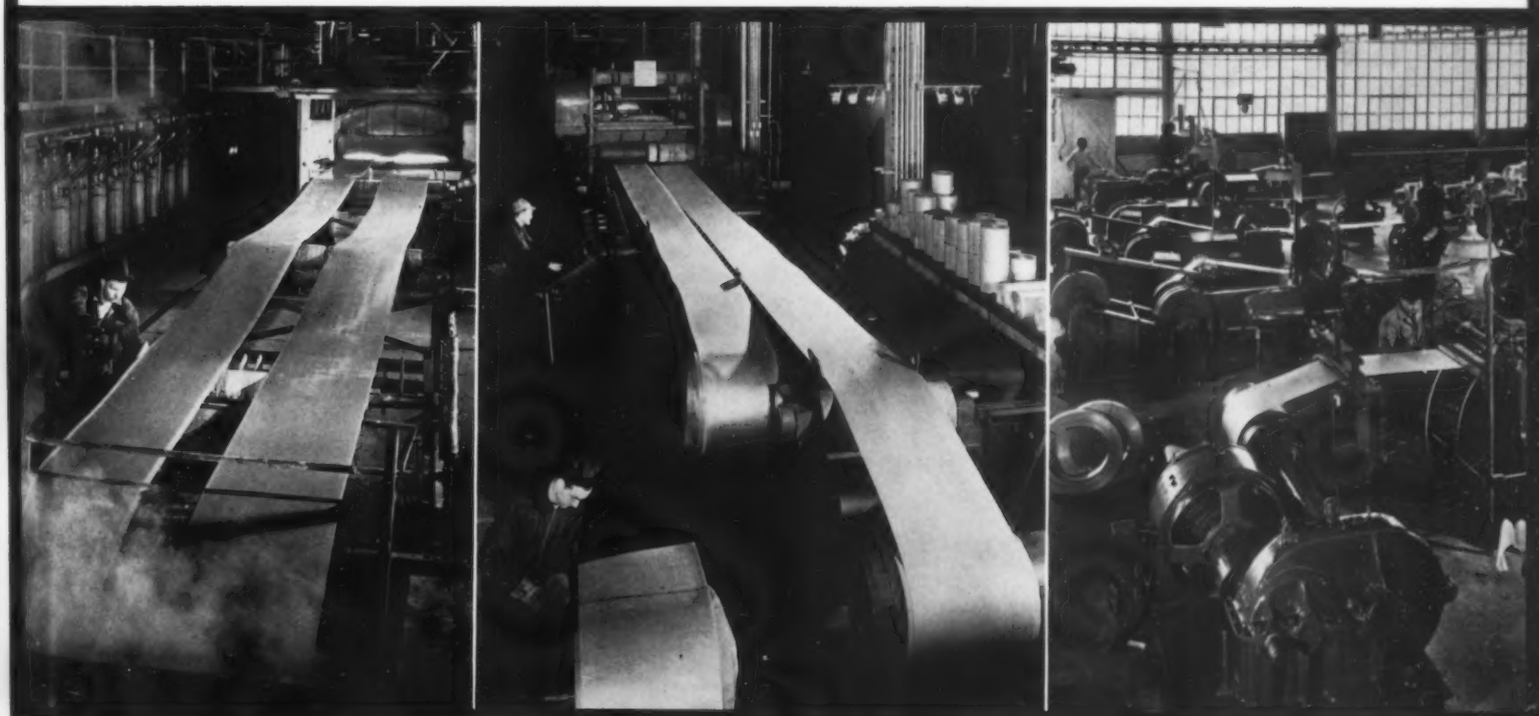
There is also a 10 in. and 36 in. x 20 in. four-high reversing mill similar to the preceding stand, except in mill width. This unit is used for the intermediate and finish rolling of strip up to 16 in. wide. The mill is driven by a 500 hp., 200–400 rpm., 600 volt d-c. motor, through a gear reduction of 2.19:1. Roll speeds of 91.5–183 rpm. are attained, with strip speeds of 250–500 ft. per min. Each of the 20 in. reels is driven by a 150 hp., 250–1000 rpm., 600 volt d-c. motor.

The skin rolling for all widths of strip up to 30 in. is accomplished in a two-high 26 in. x 34 in. non-reversing mill. Centerless coils 20 in. inside diameter, weighing up to 350 lb. per in. of width or 10,500 lb. total, are given a temper pass in this unit at speeds ranging 125–250 ft. per min. Housing post areas in this mill are 350 sq. in. Forged alloy steel rolls run in 26 in. oil film bearings having a capacity of 1,109,100 lb. at 15 rpm. The bearings are housed in cast steel chocks with latch type retaining clamps. Cylinders in the bottom chocks give facilities for balancing the top roll. Screw-downs are driven by two 15 hp., 800 rpm., 230 volt d-c.

(Left) Stainless strip is continuously normalized in direct-fired furnaces at temperatures of 1450 and 1950 degrees F., respectively, for straight chromium and nickel-chromium types.

(Center) Stainless strip leaves the five multi-strand continuous normalizing and pickling units with a uniformly clean surface of silvery luster.

(Right) In this department, coils may be trimmed or slit to exact dimensions to meet the requirements of the customer.



C. J. DUBY, *Chief Engineer*
Warren District

R. H. BAHNEY, *Chief Engineer*
Central District

motors, connected by a 14 in. magnetic clutch. The screws are 12 in. in diameter.

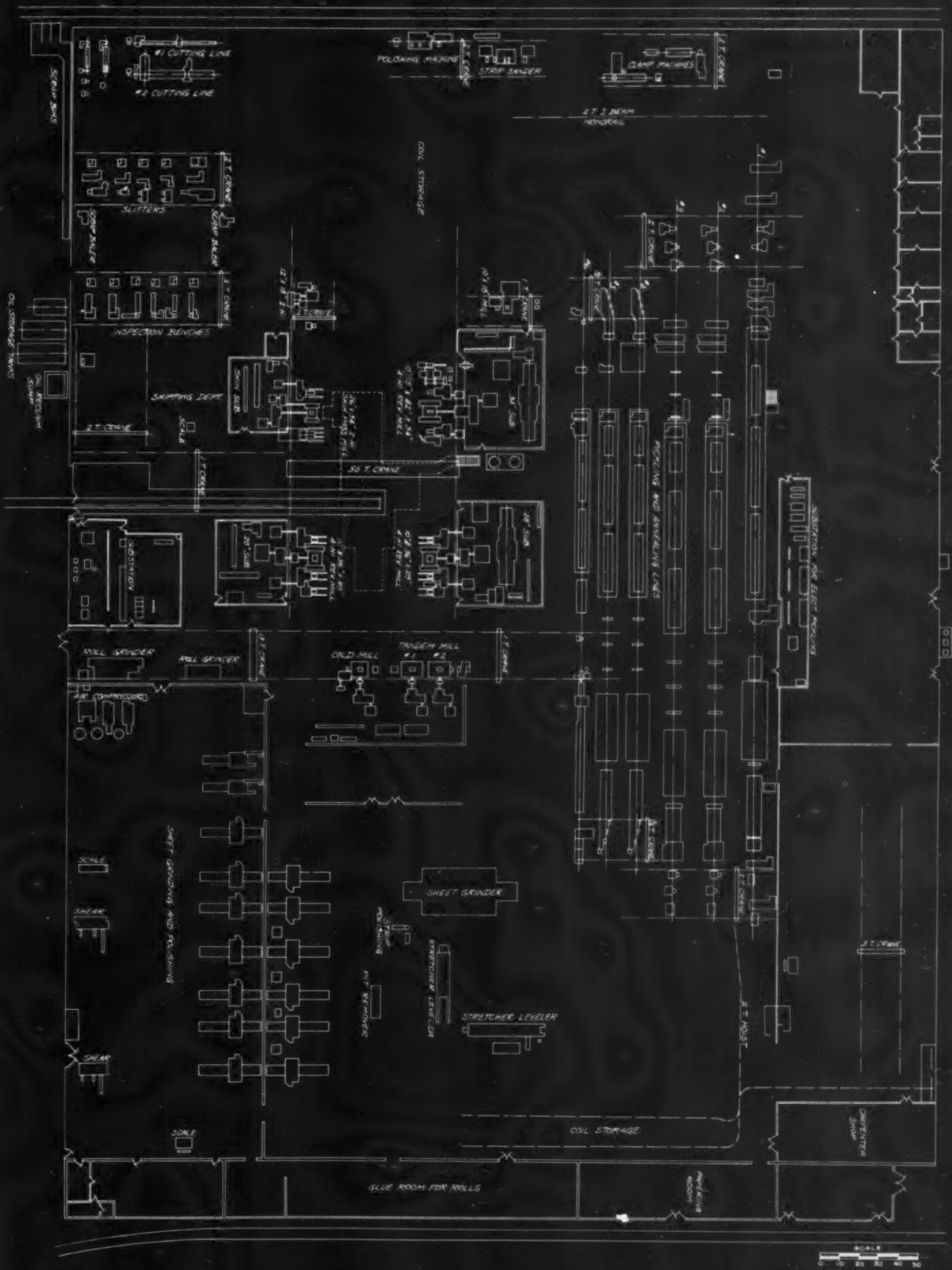
This mill is driven by a 200 hp., 400–800 rpm., 250 volt d-c. motor, through a reduction gear with a ratio of 23.4:1. The pinion stand is combined with the reduction gear. The 26 in. pinions are of forged alloy steel, while the gear is cast steel. Universal spindles and couplings with spring balanced type carrier are provided. Entry and delivery guides are also provided, of plate and cast steel construction with removable brass wearing strips. A wiper is installed on the entry side of the mill, as is a 16 in. deflector roll, a pay-off reel with a 25 kw. drag generator, and a hydraulically operated lift and traverse for charging coils to the reel. There is also a 20 in. collapsible reel, driven through an 18.2:1 gear reduction, by a 75 hp., 250–1000 rpm., 250 volt d-c. motor, and a tension roll machine driven by a 75 hp., 400–800 rpm. d-c. motor.

Each of the new mills is provided with a grease lubricating system, while a separate oil system serves the oil film bearings on the temper mill. All drives and pinions are lubricated from an oil system of 170 gal.

Very narrow widths of strip are produced by the slitting of wide strip, for which five units such as this have been installed.

The final inspection of the finished strip is merely the last step of a close inspection maintained throughout the entire processing.

Stainless Cold Finishing Plant **REPUBLIC STEEL CORPORATION** *Massillon, Ohio*


#1 CUTTING LINE
#2 CUTTING LINE
POLISHING MACHINE
STRIP SANDER
CAMP MACHINES
SCRAP BINS
SLITTERS
SCRAP BALER
INSPECTION BENCHES
SHIPPING DEPT.
COIL STORAGE
OIL STORAGE TANKS
SCALE
SUBSTATION
SOAKING PITS
SOAKING PITS
SOAKING PITS

per min. circulating capacity, 5000 gal. storage capacity, complete with filters, pumps, electric alarm, etc. There is a hydraulic system, with accumulator, pumps, etc., for roll balance service, and another separate hydraulic system for auxiliary mill equipment. Circulating systems for the soluble coolant used on the mill rolls range 2000–3000 gal. storage capacity and 150–200 gal. per min. circulating capacity, and include coolers and strainers to remove particles .003 in. and over in size. This equipment is located in roomy, well-designed cellars under the mill floor.

Power supply to the main drives of the four new mills is somewhat unusual in that some of the main generators have been combined on a single unit. In the 34 in. motor room is a unit composed of the following: one 75 kw. 250 volt exciter, one 150 kw. 456 volt unwinding reel booster, one 1000 kw. 600 volt generator for the 34 in. mill drives, one 200 kw., 250 volt generator for the 2-high skin pass mill drives, and one 115 kw., 360 volt winding reel booster, all driven by a 2000 hp. 2300 volt, 720 rpm. synchronous motor. Another eight-unit booster set in the temper mill motor room completes the control for that unit. Likewise, in the 28 in. mill motor room, there is a unit as follows: one 75 kw., 250 volt exciter, one 150 kw., 456 volt unwinding reel booster, one 750 kw., 600 volt generator for the 28 in. mill drives, one 500 kw., 600 volt generator for the 20 in. mill drives and one 115 kw., 360 volt winding reel booster, all driven by a 2000 hp., 2300 volt, 720 rpm. synchronous motor. A seven-unit set in the 20 in. mill motor room furnishes the various boosters for the control of that unit.

The mills previously existing in this plant included the following:

One four-high two-stand tandem mill, 15 in. and 32 in. x 20 in., each stand driven by a 300 hp., 400–1200 rpm., 230 volt d-c. motor. Gear ratios are 22.36 and 18.2 respectively, with roll speeds of 17.9–53.7 and 21.6–64.8 rpm., and strip speeds of 70.5–211.5 and 85–255 ft. per min. The reel is driven by a 15–35 hp., 400–1600 rpm., 230 volt d-c. motor.

One four-high stand, 9¾ in. and 24 in. x 20 in., driven by a 300 hp., 400–1200 rpm., 230 volt d-c. motor through a gear reduction of 9.88:1, giving mill speeds of 40.3–120.9 rpm., or 100–300 ft. per min. The reel for this mill is driven by a 35–100 hp., 225 rpm., 230 volt d-c. motor.

One two-high mill, 12½ in. x 18 in., driven by a 150 hp., 400–1200 rpm., 230 volts d-c. motor. Gear ratio, 14:1, and mill speed 28.5–85.5 rpm., or 93.2–279.6 ft. per min.

One two-high mill, 10½ in. x 12 in., driven by a 50 hp., 400–800 rpm., 230 volt d-c. motor. Gear ratio, 10-1, and mill speed 40–80 rpm., or 104.4–208.8 ft. per min.

The old four-high stands are now used for breakdown and intermediate rolling on widths up to 16 in., while the two small two-high units are used for temper rolling of narrow widths and slit stock.

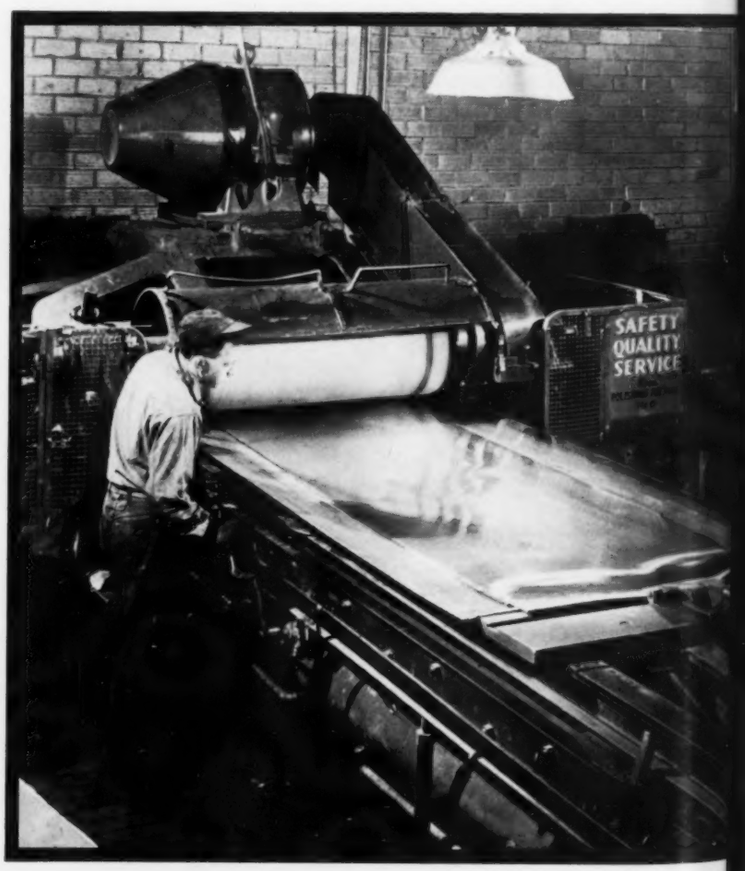
Mill production at present is about evenly divided between the straight chromium types and the nickel-chromium types. An analysis of widths produced shows 82 per cent 16 in. wide or less (averaging 12.8 in.), 16 per cent 16–24 in. wide (averaging 19 in.) and 2 per cent 24–30 in. wide (averaging 25 in.). With the new equipment it is expected to reach gauges down to .008 in. or even less.

Roughing is effected at strip speeds averaging 160–180 ft. per min., and finishing at 190–250 ft. per min. The mills used for finishing passes are provided with devices for coiling paper between the strip layers on the coils, driven through belts from the reel drives.

There are five continuous multi-strand normalizing and pickling lines, consisting of pay-off reels, spot welder, looping pit, furnace, acid tanks, scrubber, and recoiling reels. The furnaces, varying slightly in design, are about 35 ft. long, and are open-fired, using natural gas in a low pressure system. Temperatures, under automatic control, are carried at about 1950 degrees F. for the nickel-chromium types and 1450 degrees F. for the straight chromium types. An excess of air is used for combustion, about 6 per cent of oxygen being desirable in the furnace atmosphere.

Acid tanks in four of the lines are provided with electrolytic apparatus, one generator unit per line, rated at 3000 amperes at 15 volts or 1500 amperes at 30 volts. The current is led to stainless electrodes placed above and below the strip passage line. For electrolytic pickling the solution carries 4 to 6 per cent of acid, either sulphuric or nitric acid being used. In pickling without electrolytic equipment, solutions may range 10 to 20

The stainless finishing facilities at the Massillon plant also include fifteen polishing machines, capable of taking sheets up to 68 in. wide x 24 ft. long.



SCALE

GAS BOOSTER STATION

GAS MIXING STATION

CONTROL HOUSE

GAS PRODUCERS

#5 #4 #3 #2 #1

40'-0"

40'-0"

18'-6" HEARTH

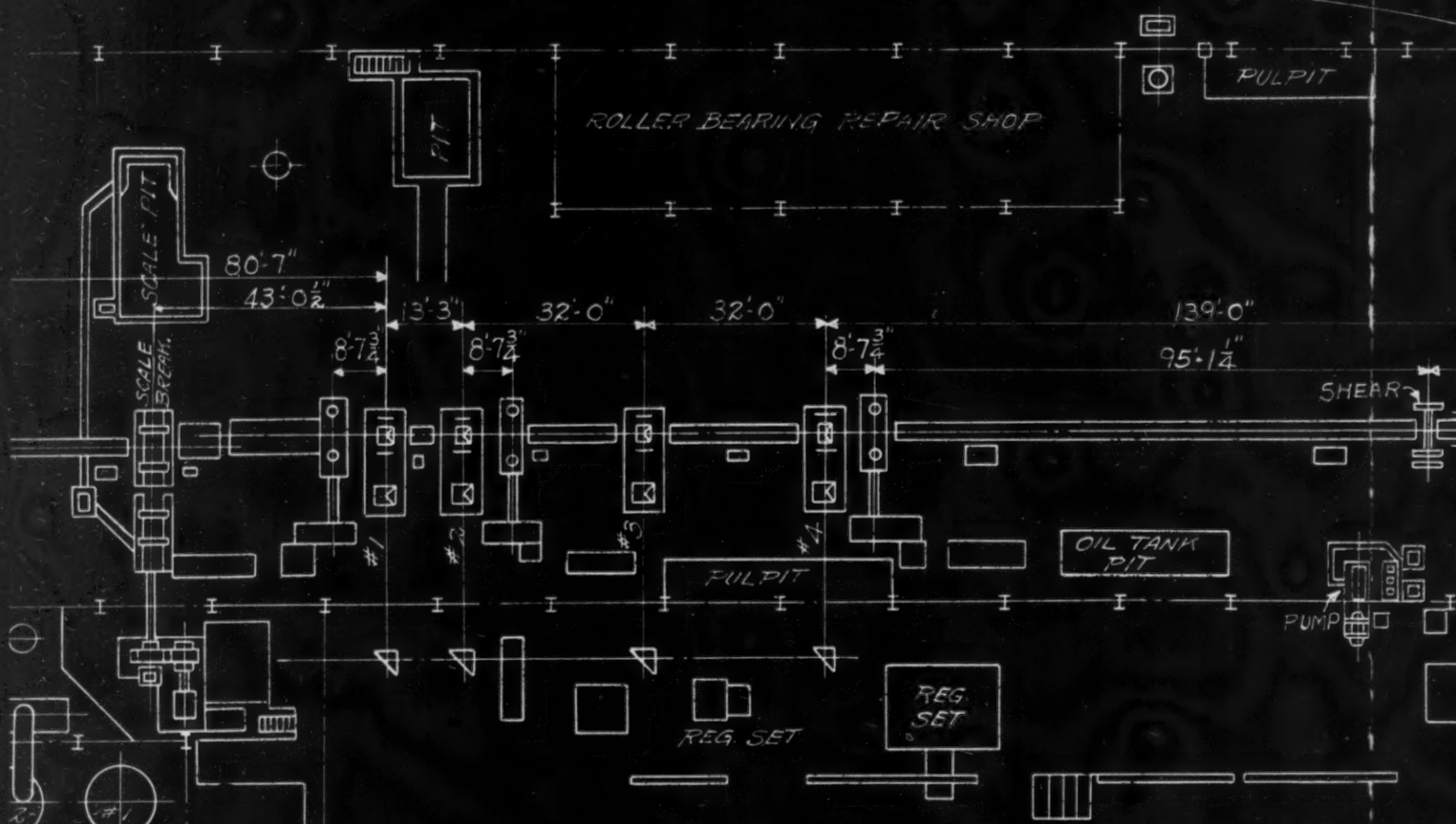
18'-6" HEARTH

18'-6" HEARTH

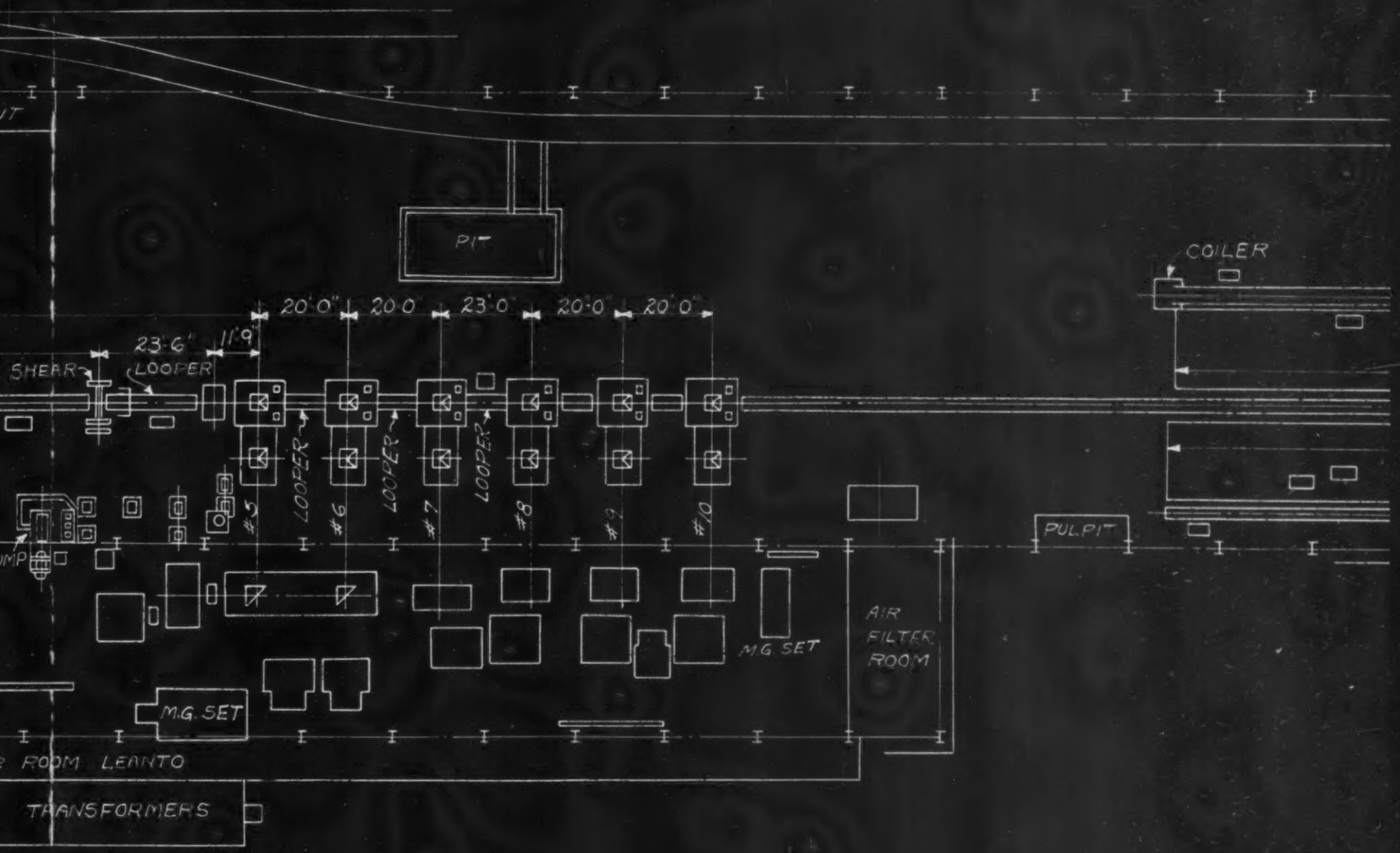
SCALE PIT

SCALE BREAK

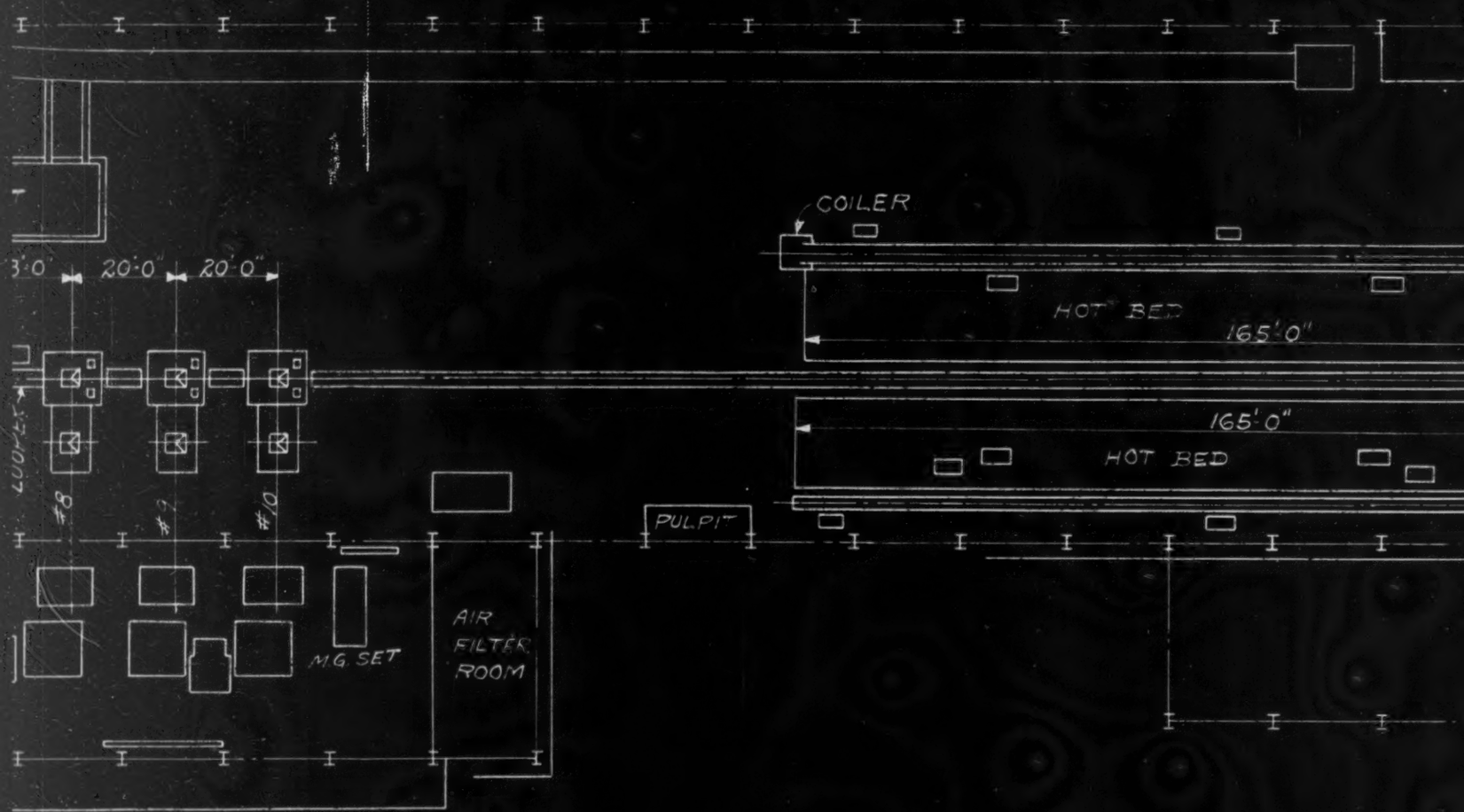
Hot Strip Mill REPU

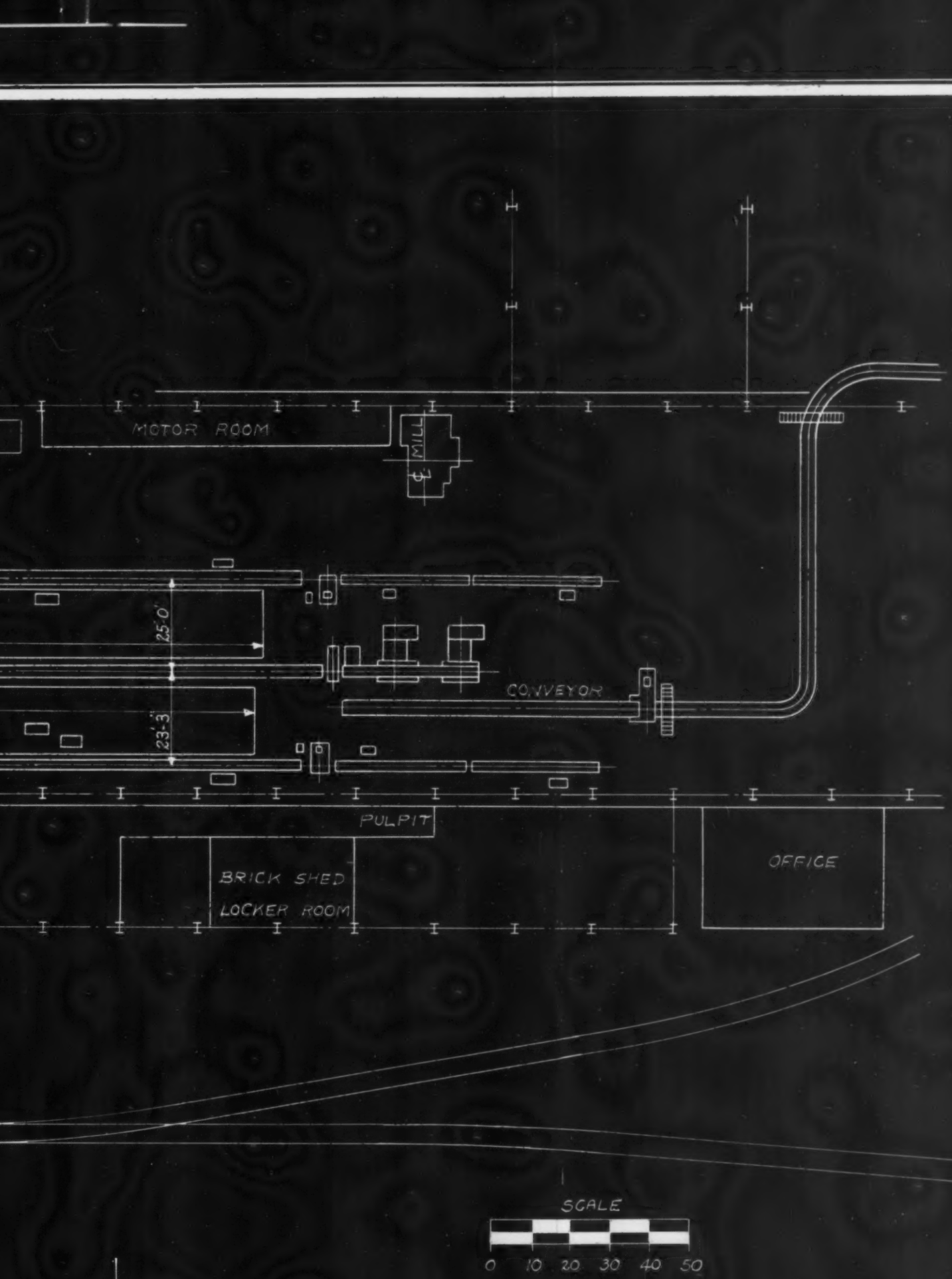


REPUBLIC STEEL CORPORATION *Warren, Ohio*



ORATION *Warren, Ohio*





SCALE

0 10 20 30 40 50

per cent of sulphuric or nitric acid, and 130–150 degrees F. in temperature. Small amounts of hydrofluoric acid may also be added. Two of the lines have a speed range of 5–20 ft. per min., and the remaining three, 6–48 ft. per min. Actual processing speeds vary with the gauge and type of material, averaging about as follows:

Gauge, in.	Speed, ft. per min.	
	Chromium types	Nickel-chromium types
.140	....	5
.109	9.5	6
.045	9.5	8
.025	15.5	10
.015	21.0	12

There is also a continuous pickling line without a normalizing furnace or electrolytic apparatus, with a speed range of 4–24 ft. per min.

The normal processing of the hot-rolled nickel-chromium types consists of an annealing and pickling, followed by a cold reduction, another anneal and pickle, another cold reduction, and a final anneal and pickle. For greater reductions, one or two additional steps may be necessary to complete the process, running to as many as four steps of cold reduction and five annealings and picklings. An annealing is necessary with approximately every 50 per cent total reduction. From six to ten passes may be used to obtain a total reduction of 50 per cent, using a reduction of 10 to 12 per cent in each of the earlier passes, and dropping down to 2 to 5 per cent for the later passes. The processing of the straight chromium types is similar except that the material is box annealed at 1475 degrees F. before pickling and cold rolling. This material is given one pass through a scale-breaking unit between the box annealing and the pickling.

Skin passing is performed in the two high mills to a degree as dictated by the temper desired in the finished strip. Five slitting units serve for the production of narrow widths. Close inspection of the strip is maintained throughout the entire processing. An inspection bench is provided at the end of each pickling line. In addition, there are six inspection lines for the final inspection of the finished material.

All of the cold strip finishing equipment, together with the sheet polishing and grinding equipment is housed in a building 440 ft. x 599 ft. 6 in. Control panels for the various processing lines have been mounted on elevated cat walks, leaving the floor clear of equipment of this nature.

No longer a jewelry store item, stainless steel has "come of age," and now constitutes an appreciable tonnage item, and the application of modern continuous methods to its production is an important stride toward a still wider application of its many beneficial properties in all lines of manufacturing and construction activity.

STRIP MILL DATA—STAINLESS STEEL ROLLING

Mill	Characteristics	Roll diameter, in.		Roll length, in.	Motor			
		Work roll	Back-up roll		Hp.	Voltage	Rpm.	Type
Warren hot strip mill								
Roughing scalebreaker	1 stand, 2-high	24	..	42	1200	2300	585	Induction
No. 1 edger	Vertical	..	..	..	300	250	400/800	d-c.
No. 1 rougher	1 stand, 2-high	25	..	42	....	....	.....	.....
No. 2 rougher	1 stand, 2-high	25	..	42	....	....	.....	.....
No. 2 edger	Vertical	..	..	..	100	250	400/800	d-c.
No. 3 rougher	1 stand, 2-high	25	..	42	3500	2300	315/405	Induction
No. 4 rougher	1 stand, 2-high	25	..	42	....	....	.....	.....
No. 3 edger	Vertical	....	..	..	100	250	400/800	d-c.
No. 5 finisher	1 stand, 4-high	16½	32	42	5000	2300	270/450	Induction
No. 6 finisher	1 stand, 4-high	16½	32	42				
No. 7 finisher	1 stand, 4-high	16½	32	42	2500	600	225/450	d-c.
No. 8 finisher	1 stand, 4-high	16½	32	42	2000	2300	270/450	Induction
No. 9 finisher	1 stand, 4-high	16½	32	42	2000	2300	270/450	Induction
No. 10 finisher	1 stand, 4-high	16½	32	42	2000	2300	270/450	Induction
Massillon cold strip mills								
Reversing cold mill	1 stand, 4-high	10/15	42	34	1000	600	400/800	d-c.
	Reels (2)	20	..	..	(2) 250	600	250/1000	d-c.
Reversing cold mill	1 stand, 4-high	6/10	36	28	800	600	240/480	d-c.
	Reels (2)	20	..	..	(2) 200	600	250/1000	d-c.
Reversing cold mill	1 stand, 4-high	6/10	36	20	500	600	200/400	d-c.
	Reels (2)	20	..	..	(2) 150	600	250/1000	d-c.
Cold mill	1 stand, 2-high	26	..	34	200	250	400/800	d-c.
	Reel	20	..	..	75	250	250/1000	d-c.
Tandem mill	2 stands, 4-high	15	32	20	(2) 300	230	400/1200	d-c.
	Reel	....	..	..	15/35	230	400/1600	d-c.
Cold mill	1 stand, 4-high	9¾	24	20	300	230	400/1200	d-c.
	Reel	....	..	..	35/100	230	225	d-c.
Cold mill	1 stand, 2-high	12½	..	18	150	250	400/1200	d-c.
	Reel	....	..	..	15	230	400/1200	d-c.
Cold mill	1 stand, 2-high	10½	..	12	50	250	400/800	d-c.

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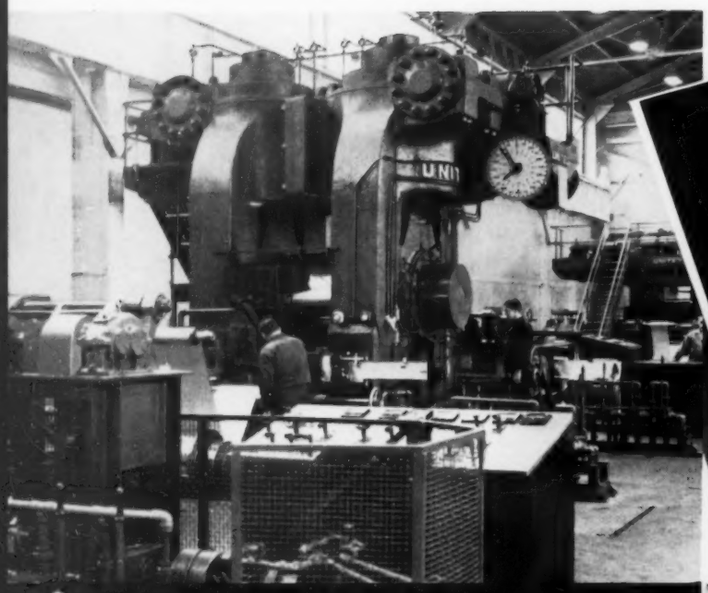
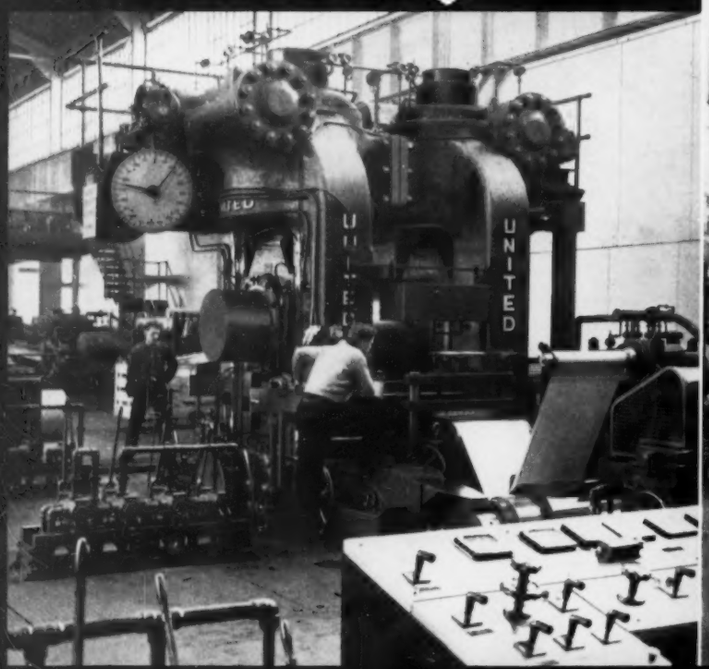
ROLLING STAINLESS



34" REVERSING COLD MILL

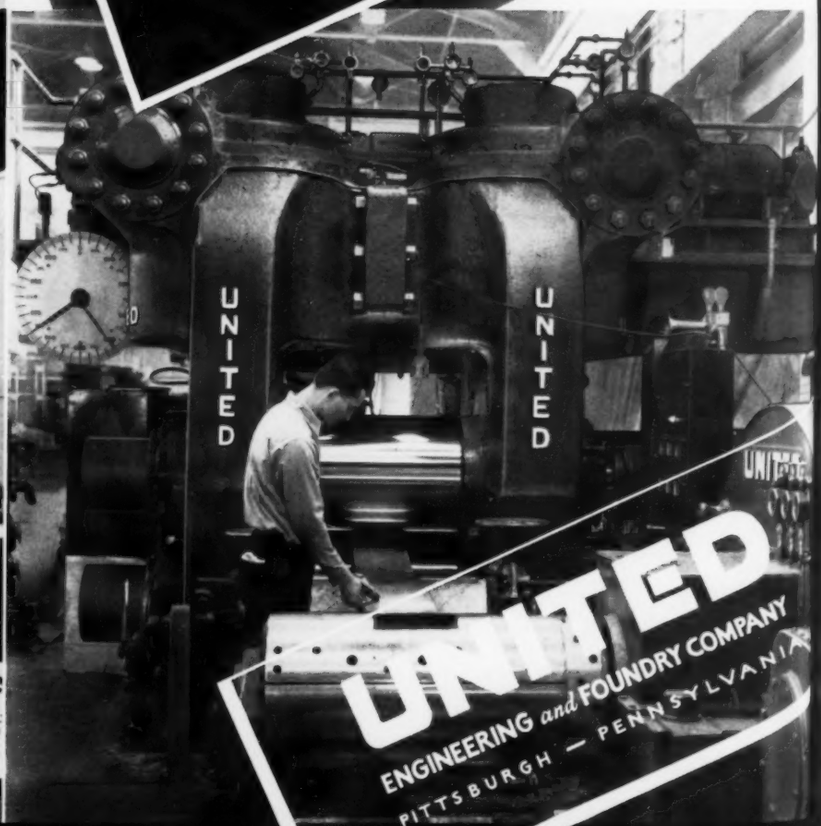
2-HIGH TEMPER PASS MILL

28" REVERSING COLD MILL



THESE MILLS ARE NOW IN DAILY PRODUCTION

Rolling Stainless Steel Strip



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BILLET GRINDING

By A. ROUSSEAU, *Abrasive Division*

NORTON COMPANY

WORCESTER, MASS.

This paper is the last of four forming a symposium on the conditioning of steel surface. The first three papers appeared in previous issues of the IRON AND STEEL ENGINEER.

Presented before A. I. S. E. Annual Convention, Pittsburgh, Pennsylvania, September 26-29, 1939

▲ PRACTICALLY all tool steels and high grade alloy steels are sensitive and develop surface defects under heating or cooling stresses as well as hammer or rolling operations. To obtain the best possible finished product, these defects must be removed prior to the finishing operations. Unless properly removed these surface defects in the billet will affect the strength and mar the quality of the finished product.

It is not difficult to find and remove defects which are plainly visible and several methods are used more or less successfully. In some mills the defects are "spot ground." Other methods are to remove the defects with chisel and air hammer or to burn them out with special acetylene torches. These methods have the advantage of relatively low cost, but the quality of the resultant product is not always what might be desired.

Grinding is generally recognized as the one method which produces the best quality of work. By this method all scale is quickly and completely removed, leaving a clean bright surface on which it is possible to readily detect not only the gross imperfections but also the smallest cracks which are concealed by the scale or otherwise invisible until the surface has been ground. These defects can then be removed by grinding in the same operation, thus saving handling and also leaving a good surface for the subsequent rolling operation.

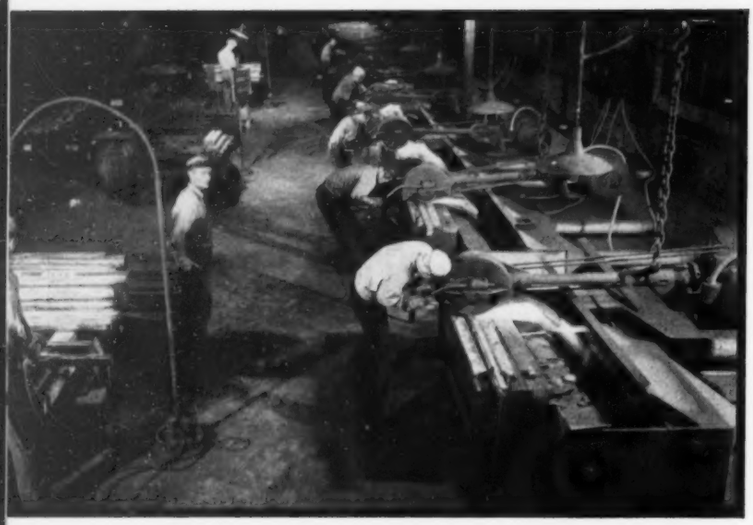
Pickling is sometimes used to disclose the cracks and seams, but this does not, of course, remove any of the defects. Pickling must be followed by some other operation to remove the defects. Grinding on the other hand not only uncovers and discloses the defects but also removes them.

On the more costly steels, it is important to remove no more material than necessary to clean the surface and remove whatever defects are there disclosed. Grinding wheels can be made to cut from a few thousandths of an inch to any depth which may be necessary. The amount of steel removed can be reduced to the absolute minimum required to produce a finished product free from surface defects, thus preventing any unnecessary waste of costly material.

Billet grinding is not a new process, having been started about 30 years ago. The first kind of steel to be ground in billet form was self-hardening high-speed steel. The reason is evident. No. other tool could cut this extremely hard material. Later certain grades of alloy steel that had to be perfectly free from surface defects were ground in billet form. Still later it was found necessary to grind practically all chrome-nickel and high chrome steels which are known for their stainless or heat resisting properties. Thus, as new grades of steel are being developed, the field is continually increasing where billet grinding is required.

During these years much progress has been made in the development of superior grinding wheels and in better grinding methods. Billet grinding is now done

View of billet grinding operation, using 16 in. swing-frame machines with suction chamber type of dust exhaust.



Billet grinding, using 18 in. swing-frame machines with box type dust exhaust.

not only much faster but with an accompanying improvement in quality. By these improvements the cost has been reduced to the point where grinding can compete with other cleaning methods which were formerly considered less costly.

THE GRINDING PROCESS

Most men connected with steel mills are familiar with billet grinding, the methods and machines used. A brief outline of present practices and procedures is necessary, however, to make this paper complete. The majority of billet grinding is done using swing frame machines mounting 14, 16, 18 or 20 in. diameter grinding wheels in widths from 2 to 3 in. Some inspection grinding is done with portable grinders mounting 6 or 8 in. diameter grinding wheels. Today nearly all billet grinding is done with resinoid or rubber bonded wheels running at a speed of about 9500 surface ft. per min. Only steel that is very sensitive to heat stresses is now ground with vitrified bonded grinding wheels running at a speed of about 5500 surface ft. per min. It has been found that with the slower running vitrified wheels the danger of producing grinding cracks is less. However, the rate of production and grade of finish is much better with the faster running resinoid or rubber bonded wheels. The rate of production as judged by the rate of material removed per hour varies greatly between the steel mills. The kind and size of steel ground as well as difference in method and practices are responsible for much of this variation. As a rule we find that the higher the tensile strength of the steel the more difficult it is to grind the steel and we must expect lower production and higher wheel wear.

The cost of grinding is almost directly comparable to the percentage of material removed and follows closely the variations in amount of grinding necessary on different kinds of steel. Small billets with more area to be ground per unit of weight will cost a little more than large billets or blooms with less area to be ground per unit of weight. However, the smaller billets have usually been rolled down to a smaller size and consequently the defects have been elongated and are more shallow. It then follows that the amount of material removed per square inch of surface will be less for smaller billets and the cost of grinding is not proportional to the area ground.

The wheels used on swing frame machines for billet grinding must generally be made with coarse grit and of fairly hard grade. Most of the wheels are operated in such a manner that the corners do a good part of the work and the face is more or less rounded. As comparatively high pressures are more effective, the cutting grains must be anchored deeply and firmly enough to get the best economy.

Certain kinds of steel, particularly stainless and heat resisting alloys, may require a better grade of finish to avoid the possibility that grinding scratches will show in the finished product. In that case it is advisable to use fine grain resinoid wheels or rubber bonded wheels. As the rubber wheels are affected by grinding heat to a much greater degree than resinoid wheels, it is important to use more moderate pressures with rubber wheels. If proper pressures and very judicial operation can be maintained, the grinding cost with rubber bonded wheels will not be much higher than with resinoid wheels.

MECHANICS AND ECONOMY IN BILLET GRINDING

Casual observation of snagging (on floor stands and under swing frames) is not likely to suggest that such grinding operation would lend itself to scientific analysis. Irregular shape and condition of the work and noise and vibration present would seem to defy classification of causes and effects, under the laws of mechanics. Even laboratory tests, with conditions controlled as closely as possible, are subject to grave "experimental error"

However, by application of the law of averages to results from many tests of the same nature and by comparison of averages with known laws of mechanics, certain principles affecting economy are made evident. Often the limit of application of one or more kinds of economy measures already has been reached on a given operation. Sometimes a single trial will not demonstrate a potential saving because of unforeseen complications. On the whole, however, there is always the chance of lowering grinding costs when the management has an accurate understanding of fundamentals.

With a given grinding wheel, two important mechanical factors under control which affect economy are wheel speed and grinding pressure. Increase in either of these factors generally increases the economy of grinding. Application of these factors will be discussed from the standpoint that any increase in the rate of production is a gain in economy so long as there is no neutralizing rise in cost from some other direction. A higher rate of production means lower labor and overhead cost per unit of product.

1. *Wheel Speed.* From a simple geometrical consideration, the amount of material removed from the work under constant pressure grinding is the same for each revolution of the wheel at a given diameter. Therefore, rate of cut is proportional to surface velocity of the wheel. In practice and within limits, rubber and resinoid wheels approach a fulfillment of this geometrical prediction. Vitrified wheels do also, but within more narrow limits: they are more likely to digress because of increased vibration at higher speed.

Safety is the most important limiting factor of high wheel speed. Maximum safe speed depends upon type of bond, bonding strength in the wheel and type and condition of the machine. Practical maximum speeds commonly quoted are 6000 surface ft. per min. for vitrified snagging wheels and 9500 for the rubber and resinoid types.

Geometrical prediction for rate of wheel wear is the same as for rate of cut. In other words, as the rate of cut is increased by increasing wheel speed, so does the rate of wheel wear increase in proportion. Therefore, theoretically, the rate of wheel wear also varies in proportion to the wheel speed. Consequently, the wheel cost per unit of material removed remains constant, but the higher wheel speed reduces labor and overhead per unit of work removed.

TABLE I

Effect of Wheel Speed

Wheel used . . . . . 12 grit hard resinoid
Work and machine . . . . . Stainless steel, swing frame
Grinding pressure . . . . . 175 pounds

Wheel speed, surface ft. per min.	9600	8600	6500
Wheel diameter, in.	16	14½	11
Wheel wear, cu. in. per hr.	10.5	12.2	10.8
Steel removed per hr.	10.2	9.4	6.5
Ratio, material removed to wheel wear	.97	.77	.60
Cost per lb. material removed:			
Wheel cost	4.4	5.5	7.1
Labor and overhead	9.8	10.6	15.4
Total, cents	14.2	16.1	22.5

2. *Grinding Pressure.* The general effect of greater pressure is higher rates of cut and of wheel wear in such order as to lower total grinding cost. Such effect is more pronounced with rubber and resinoid wheels than with vitrified wheels. Improved economy is thought to be due to broader contact. The face of a snagging wheel in use is always more or less rounded. More pressure sinks it further into the work and thus broadens contact. The advantage due to higher pressure is positive. When higher rates are gained by use of a softer wheel at the old pressure, the net result may be either a gain or loss in economy.

Practical limits in going to higher pressures are fatigue of operator, danger of wheel breakage and work requirements. Pressure must be kept low enough to allow the operator complete control of the operation.

Experimental results, with three different pressures on the same wheel, are shown in Table II.

Calculated grinding costs in the tables are based on these assumed constants:

Resinoid wheel, cost per cu. in. used $0.04¼
Time charge (labor plus overhead) per hr. 1.00

TABLE II

Effect of Grinding Pressure

Wheel used . . 12 grit hard resinoid at about 9000 surface ft. per min.
Work and machine . . . . . Stainless steel, swing frame

Grinding pressure	100 lb.	140 lb.	200 lb.
Wheel wear, cu. in. per hr.	7.1	19.4	28.4
Steel removed, lb. per hr.	5.2	12.6	21.6
Ratio, material removed to wheel wear	0.73	0.65	0.76
Cost per lb. of material removed:			
Wheel	5.8	6.5	5.6
Time charge (labor plus overhead)	19.2	7.9	4.6
Total, cents	25.0	14.4	10.2
Reduction from initial cost, per cent	....	42	59

GRADE OF WHEEL

In addition to the two mechanical factors, there is another factor which has an important bearing on wheel economy. This is the grade of the wheel.

When rate of cut is changed, incidental to improved economy, the question of change of grade of wheel arises. In general, a higher rate of cut is likely to call for a slightly harder or more wear-resistant wheel. Total grinding cost per unit of product is influenced by grind-

Swing-frame grinding machines with dust exhaust attached directly to each machine.

TABLE III

Pressure	Wheel wear, cu. in. per hr.	Material removed, lb. per hr.	Per cent contact
Vitrified wheel			
200	52.2	14.33	53
175	46.9	12.13	47
150	36.5	11.91	47
125	23.5	9.49	39
100	18.2	6.84	27
Resinoid wheel			
200	28.2	12.58	54
175	25.8	11.91	37
150	18.8	9.71	47
125	14.1	7.72	27
100	4.69	4.41	31

ing grade of wheel, relative to grinding conditions. This total cost is at a minimum when grinding grade is adjusted so that time charge (labor plus overhead) and wheel cost are about equal. Tables I and II show a reduction in time charge with little change in wheel cost, as rate of cut is increased. In case the time charge should fall much below the wheel cost, a more wear-resistant wheel would bring the two divisions of cost back near equality and would reduce further the total cost. It so happened that the wheels represented in both tables were too hard for minimum total cost under each respective initial condition.

There is another practical reason for a more durable wheel (harder grade) when a higher speed or higher pressure is used on rubber and resinoid wheels. Heat is generated at a faster rate and the bonds of these wheels are susceptible to wear by heat.

Treatment in the two preceding paragraphs is based on the well-established fact that a softer wheel, under the same pressure and speed, wears and cuts at faster rates. When a softer grade is used to increase rate of cut, increase in rate of wear is greater than that of cut —consequently, the time charge per unit of work diminishes while wheel cost per unit of work rises.

DISCUSSION OF ECONOMY FACTORS

Discussion in general is intended to be a statement of some of the principles which are the foundation of economy in snagging and billet grinding. They apply mainly to cases in which substantial amounts of metal are removed from areas of the work. There are a few jobs on which increased rate of cut is of little or no advantage in speeding production. For example, if a piece of work requires only skinning and if, for some reason, the wheel cannot be moved over the work any more rapidly than at present, a faster cut would save no time but would waste metal.

Magnitude of reduction in grinding cost which may be effected by changing each of the two numbered mechanical conditions depends upon how well grade of wheel has been selected for the initial conditions. Higher wheel speed and higher pressure will result in more profit if the wheel has been too hard, as illustrated by the initial conditions of Tables I and II, where time charge is high relative to wheel cost. Both tables, however, show the direction of trend that may be expected regardless of initial conditions and of initial wheel.

Geometrical predictions of effects of variations in the two factors discussed can be summarized as follows:

1. *Wheel Speed* (*constant pressure*)—Rate of cut and rate of wheel wear are proportional to surface speed of the wheel. Wheel wear per unit for work ground remains constant regardless of wheel speed. Economy is gained through the higher rate of production.

2. *Grinding Pressure* (*constant speed*)—Higher pressure increases both rate of cut and rate of wheel wear. Practical gain appears to be greater with organic than with vitrified wheels and appears in the form of faster production.

WHEEL TO WORK CONTACT

An interesting study was recently made in our research laboratories on a vitrified and a resinoid bonded wheel

Small portable hand grinders are widely used for inspection grinding.

to find the relation between pressure and actual contact time. The following conclusions were made.

As pressure was decreased from maximum, the general trend of the efficiency for the two wheels tested was downward. This tendency was definite with the resinoid wheel, but rather indefinite with the vitrified.

There was also a decrease in the amount of contact for both wheels, even though the measured runout was less under the lighter pressures. At first sight this would seem contradictory, but it shows that higher pressures cause the wheel to remain more in contact with the work, vibrating up and down with the out-of-round shape of the metal, not just hopping from one high spot to the next. The latter is the case under very light pressures. The action is identical to that of a cam and its follower. Some sort of pressure must be used to insure complete contact.

The fact that there is about 25 per cent decrease in the per cent contact of both the resinoid and vitrified wheels when pressure is decreased from 200 to 100 lb. indicates that comparison of contact of two different wheels must be made at the same grinding pressure, else there may be a basic differential of contact due to pressure difference.

GRINDING WHEEL SAFETY

Great progress has been made in recent years in improving the general quality of grinding wheels. New types of bonding materials have been introduced and variables in older bonds have been brought under control. The net result has been a minimizing of the danger of breakage in use. With certain types of wheels and on certain classes of work it is today safe to use operating speeds which were generally considered extremely dangerous a few years ago.

This favorable situation, however, bears careful watching lest we allow ourselves to be carried away by over-confidence. Many users of grinding wheels, machine builders—yes, and even wheel manufacturers themselves seem to be coming to the conclusion that it is now safe to operate all grinding wheels on any grinding machine at considerably higher speeds than have usually been considered the limit. New machines designed to operate at higher speeds than sanctioned in the safety code are being placed on the market and many old machines are being speeded up. To meet this growing demand there seems to be a growing willingness to ignore older well-established rules. This is usually due to lack of technical knowledge of the resulting low factor of safety. It must be acknowledged that in many cases the increased speed does result in increased efficiency, and where this is true it is difficult to enforce or support the doctrine of true "Safety First," but in the interest of even reasonable safety it is sometimes necessary to be satisfied with something a little short of maximum efficiency.

Let us first discuss the factor of safety. It is customary for all wheel makers to test all wheels larger than a certain minimum size, at a speed somewhat higher than the known or the recommended operating speed; usually 50 per cent faster. Since the stresses from centrifugal force increase as the square of the velocity it is frequently assumed that this test factor establishes a "factor of safety" of 2¼. If centrifugal force were the only thing to consider this would be true, but there are frequently many other stresses in a wheel while grinding. Uneven heat, vibration, side pressure, sudden impact, uneven or excessive mounting pressures all contribute their share. When added together these stresses frequently cancel the established factor of safety entirely. In other words, unless the actual breaking speed were considerably higher than the established testing speed, breakage in operation might frequently result.

The true factor of safety represents the relationship between the ultimate strength of a wheel and the sum total of all the stresses in that wheel while in operation. The established factor of safety merely represents the relationship between the stresses from centrifugal force while running free at an established testing speed and while running free at a certain operating speed. There may at times be a vast difference between the two.

In good engineering practice a factor of safety of 5 is not considered excessive when calculating proper proportions for machine parts, and for parts that are likely to be subjected to shock a higher factor is recommended. This is mentioned here merely to dispel the popular impression that for grinding wheels a factor of safety of 2¼ is liberal and that it might be satisfactory to shade this occasionally. It is actually a minimum figure, and unless it is known that the true factor is higher it is very unwise to increase the operating speed of any wheel.

Wheels can be broken by lack of adequate power. If a wheel slows down materially when the work is being applied it is an indication that sufficient power is not being transmitted to the wheel spindle. This may be due to belt slippage or the use of too small a motor. When the wheel slows down its cutting ability is also lowered and not infrequently an operator tries to compensate for the inefficiency by using more pressure. This is particularly true on offhand work such as snagging and if the pressure is at all sidewise or if the wheels are of thin cross section, breakage is apt to result.

The size of a wheel does not determine the amount of power needed. A 12 x $\frac{3}{32}$ in. cut-off wheel on average work requires a 7½ hp. motor to keep the wheel from slowing down in the cut and causing breakage when it is pulled through the work at a reasonably economical rate. On the other hand a 60 x 4 in. cutlery wheel, once it gets in motion, would probably require not more than 1 hp. to keep it going on light cutlery grinding. The amount of work done per unit of time is the most important factor. In the case of the cut-off wheel a tremendous amount of material is removed during the few seconds of contact time as compared with the very small amount of stock removal spread over a longer contact time in the case of the cutlery wheel.

Many other factors such as the suitability of the wheel for the work and operating conditions have an influence on the amount of power required. As these factors are apt to vary from time to time it is well to insure a margin of safety by providing a margin of reserve power. As a general rule it is well to remember that it may be dangerous to try to force a wheel beyond

its capacity with respect to the amount of power available.

There has been some speculation if still higher rates of production and better economy could be obtained if resinoid and rubber bonded wheels were to run at speeds higher than 9500 surface feet per minute. While it is true that resinoid wheels are run at much higher speeds when used as cutting-off wheels, these wheels are used with much lower factor of safety and must be well enclosed to guard the workmen in case of wheel breakage. Billet grinding requires a generous exposure of the wheel and the methods of handling the work are none too gentle. The recommended speeds allow for an ample safety factor, but an increase in speed of 25 per cent will increase the centrifugal force 56 per cent and unless the wheel is unusually strong, the resulting factor of safety will not be adequate.

If it were possible to run wheels at higher speed with safety, it would be necessary to build machines with better bearings and considerably more power. Stronger hoods would also be required and these might be so heavy as to be cumbersome at times. Tests on present type of machines have failed to disclose any definite benefit from higher speeds.

Many attempts have been made to develop automatic machinery for grinding billets. It is quite feasible and several times it has been done in a laboratory way. However, so far there have not been any machines made or proposed that can show lower costs than the light, flexible, individual swing frame machines now in common use. Perhaps some day a machine will be invented that can grind billets more economically than with present methods.

Wheel manufacturers are continually working to develop stronger bonds, superior abrasives and better methods. It is safe to say that due to improved grinding wheels, the grinding costs have been lowered about 25 per cent the last few years. It is reasonable to expect that the march of progress will be equally fast during the coming years and the steel industry will find the grinding wheel makers right at their side when trying to solve some new problems or meet some unexpected development.

DISCUSSION

PRESENTED BY

W. C. McCONNELL, *Plant Superintendent,* Republic Steel Corporation, Massillon, Ohio.

A. ROUSSEAU, Abrasive Division, Norton Company, Worcester, Massachusetts.

A. K. BLOUGH, *General Plant Metallurgist,* Republic Steel Corporation, Massillon, Ohio.

L. D. BOWMAN, *Works Manager,* Vanadium-Alloys Steel Company, Latrobe, Pennsylvania.

W. C. McCONNELL: I would like to ask Mr. Rousseau about the resulting product from grinding. What steps have been taken to utilize that product?

A. ROUSSEAU: I have no information of my own knowledge, but perhaps there are some people here in the room who could answer that, because I recognize the faces of some who I know utilize grinding as a method of cleaning billets.

A. K. BLOUGH: Mr. Rousseau did not explain what makes a variation in the quality of wheels. Has anybody set up to grind small billets longitudinally instead of crosswise? This seems to be a more efficient set-up to skin-grind these billets, however, there is some doubt as to whether seams can be as easily seen with longitudinal grinding marks. Is not the limit to removal of metal by grinding set by the heat generated causing grinding cracks?

L. D. BOWMAN: Mr. Rousseau gave us a very interesting paper on what I believe is a very difficult subject. He stated that he believed the cost of billet grinding had been reduced at least twenty-five per cent. I think he is rather modest in that statement. I would say it is probably closer to 50 per cent. It is not only due to the improved grinding wheels, but to the knowledge and study of the proper application of billet grinding in the past five or ten years.

Prior to that time, the grinding wheel salesman simply went to a purchasing agent and sold him a grinding wheel that had given the longest life in the plant, that he had previously been selling, and that same grinding wheel was supposed to grind all the various analyses of steel.

That condition has certainly changed. Today grinding wheel people provide an engineer to study conditions, with their own engineers, who are able to select the proper grade of wheel for economical billet grinding. It is quite true that each different analysis of steel requires a different grade of wheel.

My experience is connected primarily with the high-grade steels, such as high-speed steels, and I even find that the tungsten high speed steel requires a different grade of wheel than the molybdenum high speed steel. That just gives an example of the idea of the selection of the proper wheel.

Also you have to take into consideration the type of grinding or billet grinding that is going to be done, whether it would be spot grinding or skin or surface removal. These are two different types of grinding, requiring different wheels.

I think Mr. Rousseau didn't dwell enough on the importance of the grinding machine and the operator. Those two factors to me are just about as important as the wheel itself. The condition of the machine has a lot to do with the life of the wheel and the operator has still more to do with the life of the wheel.

Mr. Rousseau stated that it was possible that some day we could have a machine that automatically ground

(*Please turn to page 58*)

DEVELOPMENT in RECOVERY of PYRIDINE BASES

From By-Product Coke Ovens

By M. D. WALD, *Supt. Coke Plant*

REPUBLIC STEEL CORPORATION

CLEVELAND, OHIO

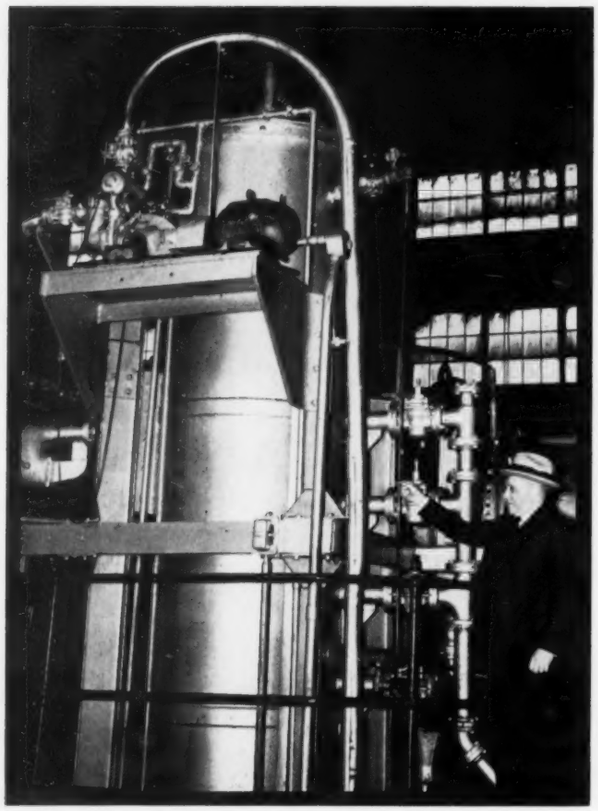
▲ THE recent discovery of sulphapyridine as a cure for pneumonia has served to accelerate an already growing demand for pyridine in the chemical industries, and to turn the attention of by-product coke oven operators to recovering the tar bases present in coke oven gas. This article describes a new, continuous method for recovering these bases that has been developed in the Cleveland plant of the Republic Steel Corporation, and that overcomes the difficulties experienced with the batch process tried in the past.

M. D. WALD

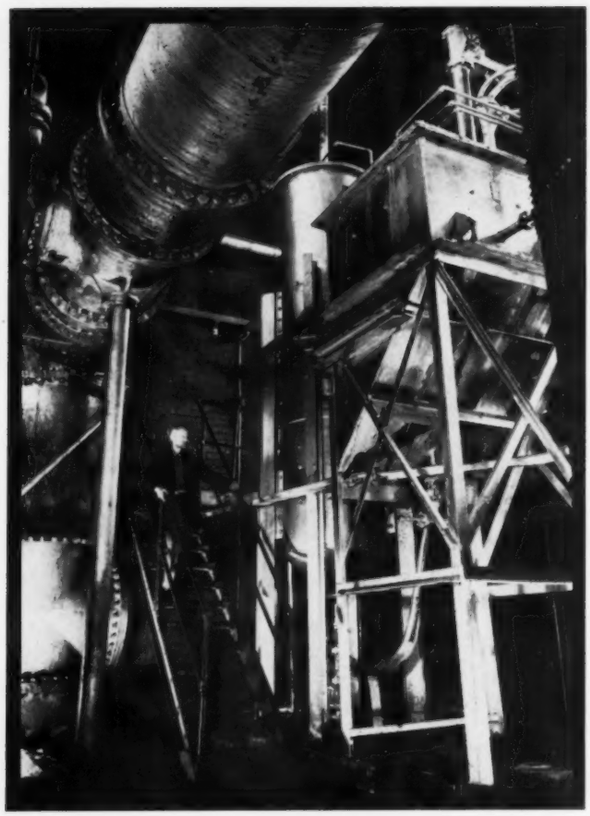
The tar bases, pyridine, picoline, lutidine, quinoline, and their homologues, are formed in small quantities in the coking of coal, either during the primary thermal decomposition of the coal, or as products of secondary reactions occurring during the passage of the gas through the coking chambers. The higher boiling, less valuable bases tend to condense in the tar, and are recovered from the light oil and carbolic oil fractions in the distillation of the tar. This is done by treating the oils with sulphuric acid, separating the resulting pyridine sulphate solution, and springing the crude bases with an alkali. From the crude bases the pure products are obtained generally by distillation, drying, and fractionation.

The greater part of the lighter bases formed in carbonization of the coal, however, does not condense in the tar, but remains in the gas. In this respect the bases act in the same manner as do benzol and toluol, of which only small quantities are to be found in the tar. The bases available in the gas have been found to be of the order .15–.20 pounds per ton of coal, and they consist largely of pyridine and picoline, which alone are in demand at the present time. Coke oven gas appears to be the most important source of pyridine now available.

In the well known semi-direct process for recovering ammonia from coke oven gas the raw gas coming from the ovens is cooled, passed through a tar extractor, reheater, and finally through a saturator, where the ammonia is recovered by bubbling through a 4–8 per cent solution of sulphuric acid. Most of the water vapor in the gas is condensed in the cooling, and comes down as a weak ammonia liquor. This liquor is distilled and



This view shows the author standing by the upper section of the crude pyridine separator. The pump at the top returns the pyridine-free liquor to the saturator.



Acid solution from the saturator passes through the lye pot and into the neutralizer *(right)*. The neutralized solution then flows to the separator *(rear)* where crude pyridine is liberated.

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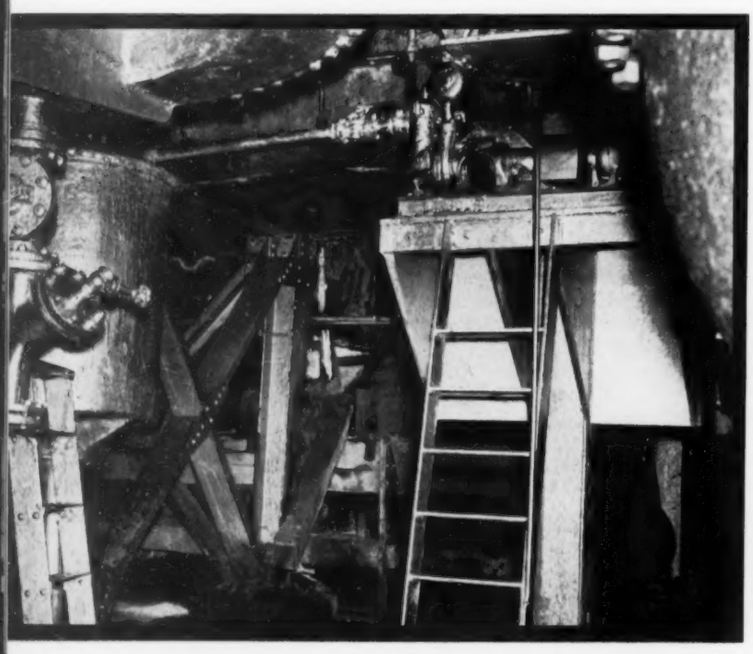
At the top is shown the small pump which continuously delivers acid solution from the lye pot *(left)* to the neutralizer where the solution is treated.



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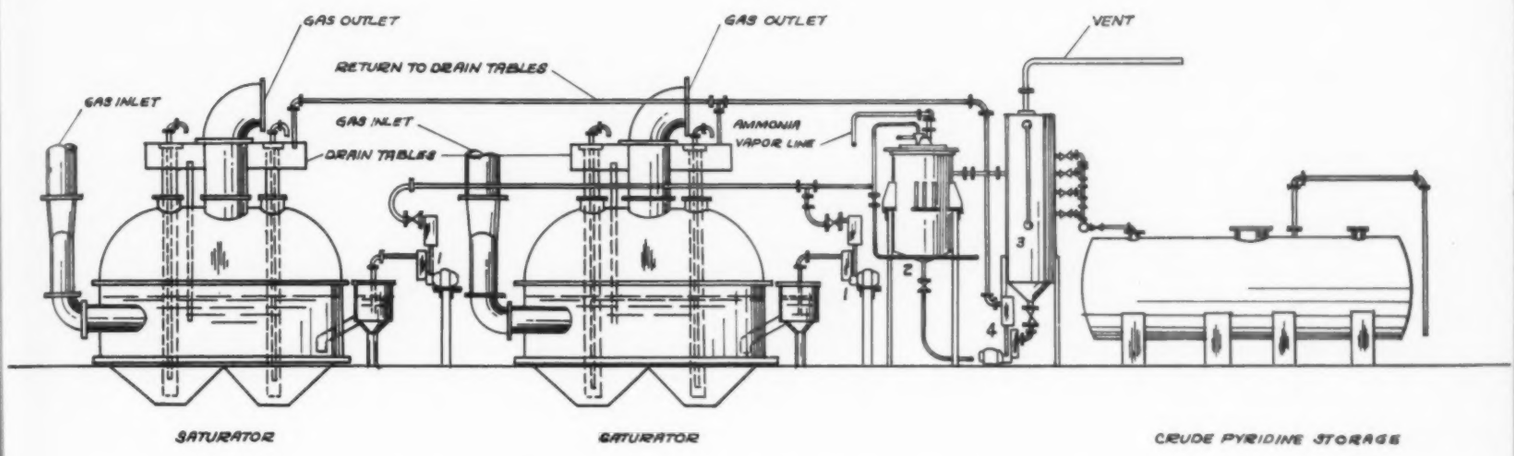
This view shows the pyridine-free solution which comes from the separator being delivered to the saturator drain table, from which it re-enters the saturator.

the ammonia vapor is added to the gas before the saturator. The sulphate of ammonia formed in the saturator is continuously removed, is dried in centrifugal driers and is stored for shipment.

The ammonia liquor has in solution part of the pyridine contained in the gas. On distillation of the liquor the pyridine is distilled off along with the ammonia, and is absorbed in the acid solution of the saturator together with the pyridine that remained in the gas. The concentration of pyridine in the saturator bath increases up to about 5–6 per cent, beyond which the bath will absorb no more pyridine. As more pyridine enters the saturator with the gas, it is carried away in the ammonium sulphate and in the gas leaving the saturator, and is lost.



In the continuous process for pyridine recovery, the saturator remains in operation indefinitely. A small quantity of the saturator solution is continuously withdrawn, stripped of its pyridine content and continuously returned to the saturator.

THE BATCH PROCESS

A process for recovering the pyridine from the saturator solution was devised and patented in 1918 by F. E. Dodge and F. H. Rhodes, and recovery equipment was installed in the plant of the Interlake Iron Corporation at Toledo, Ohio (then Toledo Furnace Company). In this process the pyridine concentration of the bath was allowed to increase to a maximum; that is, until the bath could absorb no more pyridine. The solution was then removed to a storage tank and a fresh bath was put into the saturator. From the storage tank containing the old bath the solution was pumped to a still and was neutralized or made alkaline with ammonia vapor. Sufficient heat is generated in this reaction to distil off the pyridine sprung from the solution. However, considerable water is also carried over in the distillation. The distillate was collected in receivers, part of the water was removed by adding solid ammonium sulphate, and the crude pyridine was drained to a storage tank.

When the saturator solution is made alkaline, salts of iron consisting of ferro- and ferricyanides are precipitated. A filter was provided for removing these precipitates before the solution was returned to the saturator.

This process had some excellent features. It was economical in that it employed no materials that were not already being used for the production of ammonium sulphate, and none of the acid or ammonia was lost or wasted, all of it being converted into ammonium sulphate. Unfortunately the process had objectionable features as well, and these affected the efficiency of recovery to such an extent that the Toledo plant soon discontinued the operation. The greatest difficulty was the need for removing the saturator bath when the pyridine concentration reached a maximum, which required 3 to 4 days. Unless this was done immediately as the maximum concentration developed, further absorption was stopped, and all the pyridine entering the saturator with the gas after this concentration had been reached was lost. To remove the bath, however, it is necessary to take the saturator out of operation, and this necessitates having available a fresh, clean saturator to which the operation can be transferred. In a small plant, where there is but one saturator in operation, the spare unit probably could be kept in readiness most of the time. In larger plants, where two or more saturators are constantly in operation, and there is but one stand-

by unit, this could not be managed at all regularly, inasmuch as the spare saturator is generally out of service for cleaning or repairs. The need for removing all of the bath from the saturator thus was a serious drawback to the process.

Another difficulty was that the average pyridine content of the bath during operation of the saturator was quite high, with the result that there were serious losses of pyridine. The bases contained in the bath can easily reach 2 per cent (by weight) after 8 hours operation with a fresh saturator, and are generally 5 per cent at the end of 3 days operation. With this concentration the loss of bases in the sulphate and in the outlet gas was sufficient to hold the efficiency of recovery at a low level.

CONTINUOUS PROCESS

It was to avoid the need for withdrawing the entire contents of the saturator, with the continual changing of saturators that this practice involves, and to keep the concentration of bases in the bath at a low value, that a continuous process was developed at the Cleveland plant. With this process the saturator remains in operation indefinitely. A small quantity of the saturator solution is continuously withdrawn, stripped of its pyridine content, and is continuously returned to the saturator, much the same as light oil is continuously absorbed by and stripped from the wash oil in a benzol plant.

Referring to the drawing, the centrifugal pump 1 withdraws the solution at the rate of 4 to 5 gal. per min. from the lye pot connected with the saturator and delivers it to a neutralizer 2, which is equipped with cooling coils to prevent vaporization. The older method of allowing the bases to distil off and condensing the distillate can be followed, but the large quantity of water that distils over is difficult to separate. In the neutralizer the acid solution is made and maintained neutral with ammonia vapor from the gas liquor distillation, and the crude pyridine thus sprung from the solution together with the pyridine-free solution flows to a separator 3. From the separator the crude pyridine is drained either intermittently or continuously to a storage tank, and the neutral, pyridine-free solution of ammonium sulphate is returned to the saturator drain tables, either by gravity, or, as shown in this drawing, with a pump 4. Should the solution in the neutralizer become slightly alkaline, it is immediately turned acid again when it is discharged into the comparatively large volume of acid solution in the drain table, and any iron salts precipitated during alkalinity are quickly dissolved again. Hence in this process there is no need for filtering the pyridine-free solution. It should be noted that alkalinity in the neutralizer is to be avoided, as it makes the separation of the bases difficult and leads to ammonia losses.

With this process the pyridine content of the bath can be maintained substantially constant at about 1 per cent, and losses are reduced to a minimum. The crude product produced generally contains about 50–60 per cent bases and about 12–15 per cent water. Patent application for the process has been filed.

Operation at the Cleveland plant was begun in February, 1939 and installations have been made in the Republic plants at Warren, Youngstown, and Buffalo. In these later installations separation of the crude pyridine is continuous and the solution is returned to the saturator by gravity.

The continuous removal of the pyridine materially improves the quality of the ammonium sulphate produced. Pyridine contamination is practically eliminated and the amount of iron salts normally present in the sulphate is reduced.

Rousseau DISCUSSION

(*Continued from page 54*)

the billets, but until that time we have to give a lot of attention to the operator of the grinding machine, in order to keep the cost within reason on billet grinding.

To answer the question that Mr. McConnell asked regarding the collection of grinding materials, that can all be done very economically in connection with the dust collector for silica dust. It is also possible to collect all your grinding material through a dust collector, and in the case of expensive steel being ground, such as tungsten steel, the tungsten then is separated either by magnetic separation or by melting, and all tungsten or any other elements of value can be restored.

I would like to ask Mr. Rousseau a question. He stressed the wheel speed and pressure, which are two important factors. I can understand the control of the wheel speed, but I can't quite understand how you are going to control pressure. You have spoken of 175 lb. being an ideal pressure, but how are you going to control that with the ordinary swing-frame grinder with your operator maybe lying on it in the afternoon, when he gets tired, and in the morning giving very little pressure?

A. ROUSSEAU: The simplest way to control the pressure is to hang weights or ballast on the machine. When this is done very little manual pressure is required. In some mills, the operator practically sits on the handle bars of the machine and rides it, controlling the traverse motion with his feet. Where either of these methods are employed fatigue does not seriously affect results.

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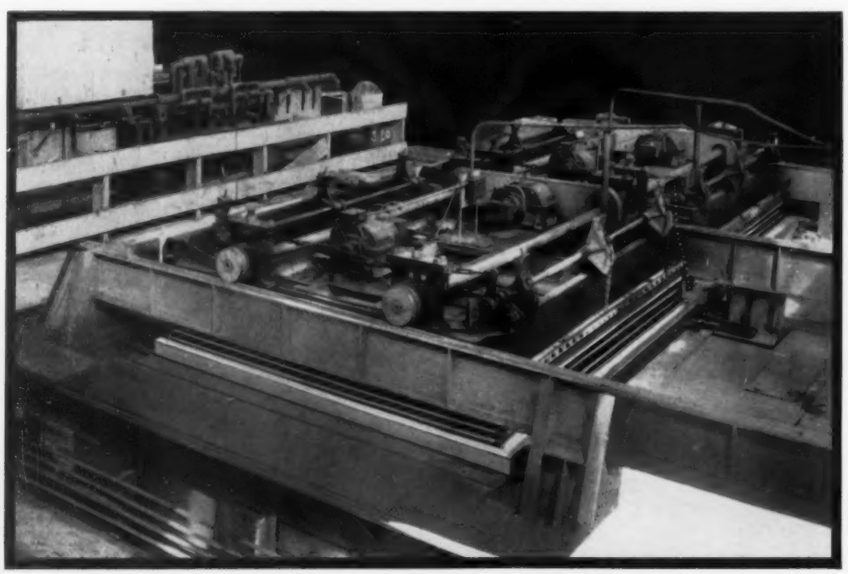
NEW PIT COVER WITH GAS-TIGHT SEAL GIVES BETTER CONTROL OF INGOT HEATING

▲ Better control of ingot heating and greater economy in soaking pit operation are objectives of a new pit cover developed by Blaw-Knox Company. The unique feature of this cover is a new way of obtaining a gas tight seal (patented). A suspended movable apron or sealing curtain around the periphery of the cover effects the seal by engaging two sand troughs. Instead of lifting or lowering the entire cover to make or break the sand seal, only the curtain is moved.

The sealing curtain has the shape of an inverted "U" The legs of the "U" are of unequal length. The shorter one engages a sand seal in a portion of the lower edge of the main frame of the cover itself while the longer leg engages a sand seal in a water cooled trough mounted on top of the pit walls. The seal in the upper trough is maintained even when the curtain is raised, thereby preventing the passage of hot gases on the inside of the curtain when the cover is partially withdrawn from the hole.

Since the movement of the seal curtain requires less than 2 hp., the mechanism for sealing is relatively light in weight. The curtain itself weighs less than 1,000 lb. It moves downward by gravity so that any foreign material tending to prevent full lowering will not cause any stress on the sealing mechanism. The parts of the curtain subjected to radiant heat when the cover is open, and certain parts of the dry seal trough, are made of alloy material.

In the new design a tight gas seal is effected between cover and soaking pit by use of a movable, inverted "U"-shaped sealing curtain.



Because of the chilling effect from the water cooled trough, the sand in the seals has no tendency to cake but stays in a loose and fluid condition. This permits good penetration of the curtain into the sand and maintains a consistent seal. This tight seal prevents leaking flame from impinging on the metal parts of the cover and track girders. Warpage, often the source of much maintenance expense, is thus avoided.

The essential novelty of the pit cover is that the movement for sealing is divorced from the movement of the cover. The cover is like a movable roof, that rolls smoothly without shock or jar, to cover or uncover the pit. Since it travels on smooth, horizontal rails with roller bearing axles, requiring not over 5 hp. for the motive drive, there is little wear on the cover mechanism as well as on the sealing mechanism.

The combined movements are controlled through one master switch. The two motor controls are interlocked so that the seal apron can move only when the cover is positioned over the hole. Ample clearance is provided for the movement of the seal curtain. The clearance between cover and top of pit walls can be set by use of adjusting screws which determine the level of the cover proper.

The cover can be designed for the use of either suspended or crowned arch brick, although the former lends itself best for most conditions.

Blaw-Knox Company has built two of these covers for an Eastern steel plant and very satisfactory service is eported from them.

REBUILD BLAST FURNACE FROM THE FOUNDATION UP

▲ National Tube Company, Lorain Ohio, will rebuild their No. 3 blast furnace from the foundation up. The rebuilt unit which will include a new cast house and trackage to facilitate hot metal handling, will have an average daily capacity of approximately 1100 net tons. This represents increased capacity over the old unit which was last rebuilt in 1924.

NEW EXHAUST HEAD USES BAFFLE-TYPE SEPARATORS

▲ A new exhaust head, manufactured by the Cochrane Corporation, insures the separation of condensate and oil from steam discharged to atmosphere and thereby prevents raining of water and oily condensate upon the roof or ground below, at the same time discharging clean, dry steam noiselessly.

The new exhaust head incorporates the principles of baffle-type steam separators used for removing oil and moisture from steam lines. Exceptional port area produces low steam velocity and minimizes pressure loss. Steam is whipped sidewise after passing through port and causes projection of entrainment against ribbed baffle surfaces. The high ribbed baffles exert a scrubbing action in addition to the centrifugal purging force. The exhaust head is of one piece semi-steel construction for 4 to 12 in. sizes and of welded plate for larger sizes.

DESIGN LINE STARTER FOR FREQUENT SERVICE

▲ A new line starter designed and built for frequent operating, jogging and for regular starting service has been announced by the Clark Controller Company. These starters consist of a multi-pole a-c. contactor and a two-element thermal overload relay.

The contactor combines the use of double break silver to silver contacts, and a vertical lift magnet. The entire assembly mounts on a steel mounting plate designed for quick removal from the cabinet. The contactor features include extra large electrical clearances, and easily accessible large size terminals for wiring. The mechanical design provides for very long life on frequent operating service.

The thermal overload relay is of the

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YOU will find the new Russell & Stoll catalog (now being mailed) a real help in your work.

Not only does it illustrate the most modern fittings for hazardous locations, wet conditions or any kind of job, but a special section is devoted to technical data on the off-standard conditions you continually meet.

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solder pot design. While reliable in operation if any damaging overload occurs, the relay will not trip out unnecessarily on normal starting, nor on overloads which are not injurious to the motor. The heaters are enclosed in covers, so that stray currents will not affect operation.

Exceptionally large wiring space is provided and concentric knockouts in top, bottom, sides and back provide means for bringing in leads at the most advantageous points. Other advantages are as follows: the terminals are easily accessible; there are large electrical and mechanical clearances; the arc shield material will withstand high temperatures and is non-carbonizing from arc.

New FARREL ROLL GRINDER
WORK MOVING TYPE
Grinds Rolls with High Finish
and Maximum Precision

In the new Farrel Type TT Roll Grinder is incorporated a traveling work table in combination with a fixed grinding wheel unit. Like the other Farrel Heavy Duty Roll Grinders, this machine will grind, with proper wheel selection, a high mirror finish free from all marks and flaws and produce perfect rolls with contours of exact symmetry and accuracy.

A sensitive reversing mechanism permits grinding up to the shoulder of the shaft. Once set, the traverse and reversal of the traveling table are automatic. The traveling table drive is designed to secure positive, vibrationless traverse, steady travel and smooth, accurate reverse.

All mechanical and electrical operating controls are within easy reach of the operator's station and so conveniently arranged that he has complete control of the grinding without leaving his position. He is thus able to maintain constant observation of the work and instant control of the machine to effect any operating change that may be necessary.

All castings are of Meehanite and are heavily sectioned and ribbed to provide the strength, rigidity and stability essential to maximum production with maximum precision.

Many other features also contribute to the low-cost, high-output, high-accuracy performance of the Farrel Type TT Roll Grinder. Details will be sent on request.

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FARREL-BIRMINGHAM COMPANY, Inc.
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TRUMBULL INSTALLS NEW SALES SCHOOL SYSTEM

▲ On March 28 and 29, the Trumbull Electric Manufacturing Company held a sales meeting in the form of a sales school at the Plainville, Connecticut, plant, which was attended by all the company's salesmen and a large delegation from distributors in the eastern and southeastern sections of the country.

A similar meeting was held at the Ludlow, Kentucky, factory April 11 and 12, which was attended by the salesmen and representatives from distributors in the mid-west and southwest sections of the country.

At these meetings discussions were held on Trumbull products and developments, and after each morning and afternoon session, examinations followed in which all in attendance participated. The so-called freshman examination was held after the first morning session; the sophomore examination the first afternoon; the junior examination the second morning; and the senior examination the second afternoon. At the close of the session, certificates of graduation were presented.

The value of having sectional sales meetings, with representatives from distributors attending, was demonstrated by the interest and enthusiasm of all participating.

GARY PLANT REPLACES OBSOLETE SOAKING PITS

▲ Carnegie-Illinois Steel Corporation is replacing a number of obsolete soaking pits at the Gary Works. Eight new pits will be built by the Amsler-Morton Company. The construction and operation will be similar to those installed by the same company at the Edgar Thomson Works of Carnegie-Illinois, more than a year ago.

The only exception in the design at the present time is that the new pits at Gary Works will be direct-fired, but provision is being made so that recuperators might be installed at a later date. The new facilities are the most modern type and are expected to result in a better fuel economy in addition to improved quality of heating.

IMPROVE LINE STARTER TO AID MOTOR CONTROL

▲ A number of improvements in the across-the-line starter, for the control and protection of polyphase squirrel cage motors up to 5 horsepower, have been announced by Cutler-Hammer, Inc.

The improvements include: (1) The streamlined, simplified, hook-on cover, held by one fastening screw, that can be removed for easy installation. This type of cover permits group panel mounting with minimum clearance between adjacent starters. The interior of the case is finished in light aluminum to facilitate wiring and inspection in poorly illuminated locations. (2) The loosening of one screw permits removal of the operating mechanism for easy wiring and conduit work. (3) The contacts—dust safe vertical—are now made of much heavier "fine" silver. Lava insulators protect contact springs against even minor heat transmission, thus insuring full contact pressure at all times.

For protection against rust, the contact springs and contact supports are made of stainless steel—all other metal parts are cadmium plated. (4) The overload relay has been made smaller in size, more accessible, with better operating characteristics. Overload trip indication is a further improvement.

The new starter is available in the following types of cover control: reset only for 2 or 3 wire remote control; start and stop reset buttons for 3 wire control; and three position selector switch for manual-off-automatic local control or 2 or 3 wire remote control. Enclosures include general purpose, water-tight and dust-tight. The starter can be obtained in open panel type for cavity or built-in mounting.

NEW LAMP UNIT AIDS INDUSTRIAL LIGHTING

▲ Development of a new two-tube fluorescent luminaire designed especially for industrial areas has just been announced by General Electric Company's lamp department at Nela Park.

An outgrowth of the familiar Cooper Hewitt fluorescent lamp, the fixture consists of a self-contained auxiliary mounted on a porcelain enamel reflector. It is rated at 200 watts and operates two 85-watt tubes (each 58 in. long) which have a combined initial rating of over 8,000 lumens.

When mounted on 10-ft. centers, this new unit, according to Nela engineers, will provide adequate industrial illumination and more light from a lesser number of tubes than any other equipment now available is able to produce.

The lamp department also announces fluorescent lamps in two different colors, namely, the original blue-white tube and a new white

PHOTOGRAPH COURTESY THE AMSLER MORTON COMPANY

They "see" what's going on in the soaking pits—

HAYS COMBUSTION INSTRUMENTS AND CONTROL INDICATING AND RECORDING INSTRUMENTS ACCURATELY DEPICT GAS PRESSURE, FURNACE PRESSURE, AIR FLOW

In the above installation a Hays "OT" Recorder (panel at the left) accurately records the gas pressure for every minute of the day and night. An Air Flow indicator (upper panel) shows continuously the air volume and flashes a warning signal when it reaches 25% of the load or lower. At the same time a Hays "D" Gage indicates the pressure *inside* the furnace. Thus is guesswork and uncertainty eliminated.

Hays Combustion Instruments have set the standard for accuracy, dependability and stamina for 38 years. They are as well known in the steel mills and power plants of the country as a monkey wrench. They can be designed to meet practically any requirement concerning indicating, recording and controlling of combustion conditions. Hays Engineer-representatives are located in all the principal cities to help industry in the solution of its combustion problems. They will be glad to serve you. Write to 955 Eighth Ave., Michigan City, Indiana.

THE HAYS CORPORATION
SINCE 1903 COMBUSTION INSTRUMENTS AND CONTROL MICHIGAN CITY, INDIANA, U.S.A.

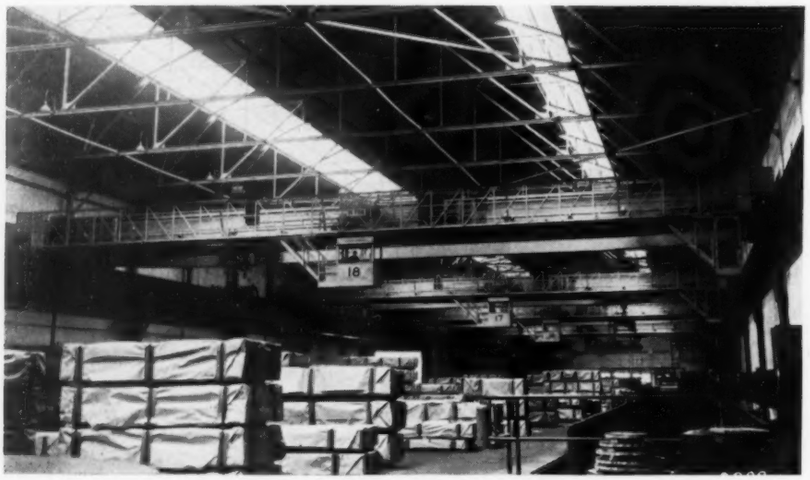
lamp. The latter, developing a color equivalent of approximately 8000 degrees Kelvin, is designed to satisfy needs in industry where color is a prime factor. This new white tube, measuring 58 in. in length, is interchangeable with blue-white tubes on all Cooper Hewitt fluorescent lamps now in service.

INDUSTRIAL CRANES HAVE MANY NEW DEVELOPMENTS

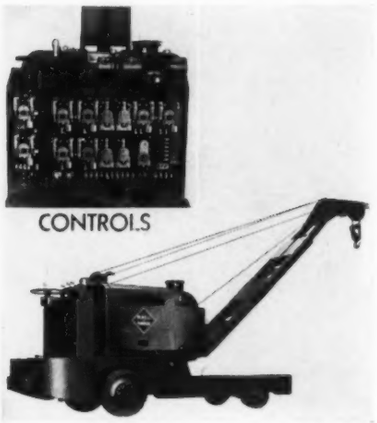
▲ The new streamlined power industrial crane brought out by the Elwell-Parker Electric Company has a rated capacity of 3,000 lb. at a 7-ft. radius and travel speed up to 5½ mi. per hr., depending on voltage of battery. Some of the advantages are: standard telescoping boom, 12 to 19 ft., slews approximately 300 degrees in 20 seconds; hook speed, 30 to 50 ft. per min.; excellent visibility from operator's position.

Storage battery or gas-electric power may be used, as desired. Four motors individually drive the travel, hook hoist, boom hoist and slew, and all may be operated simultaneously if desired. Motors governing hook hoist, boom hoist, and slew are directly accessible and are equipped with solenoid brakes.

These cranes are fitted with full magnetic contactor control equipment, protected by a removable cover. Two foot pedals are interlocked with the drive controller. When depressed, as when the operator is in driving position, the right pedal closes the power circuit and the left releases the brake. To apply the brake at will, the operator merely raises his left foot. No fuses are used in the power circuit, and this type of control permits stopping and starting on inclines.



Four 15 ton-120'-0" span Cleveland all-welded steel-mill cranes with cabs at center



Four-wheel steering mechanism is of simple design, controlled with minimum effort from a horizontal wheel. Pedals are heavily cushioned with duo long-wearing rubber composition. High pedal guards insure full protection for operator's feet and legs. The cranes are built under the Underwriters' Laboratories' re-examination service.

DON'T LET POOR CRANE SERVICE *Bottle-Neck* YOUR MILL

There are two ways by which your mill might be "bottle-necked" during busy periods:

1. By not having enough cranes to provide the service required.
2. By having cranes that **must** be held up for maintenance just when needed most.

To avoid "bottle-necking" it is wise to install Cleveland all-welded cranes at the vital points. Clevelands require minimum maintenance and assure you of dependable service always available when needed.

THE CLEVELAND CRANE & ENGINEERING CO.
Wickliffe, Ohio

CLEVELAND CRANES
ALL-WELDED OVERHEAD TRAVELING CRANES
Other products: CLEVELAND TRAMRAIL and STEELWELD MACHINERY

ENLARGE CAPACITY IN REBUILT BLAST FURNACE

▲ Youngstown Sheet and Tube Company has awarded to the William B. Pollock Company, the contract for rebuilding blast furnace "C" at their Youngstown plant. Capacity of the stack will be enlarged from 650 tons per day to around 950 tons per day. Construction of the furnace will soon be under way.

ITEMS OF INTEREST

James W. Kinnear, Jr., was appointed assistant manager of operations, Pittsburgh district, Carnegie-Illinois Steel Corporation. Mr. Kinnear, a graduate of Allegheny College and the Massachusetts Institute of Technology, joined the Carnegie Steel Company in the open hearth department at Homestead in 1923. He was appointed assistant superintendent of an open hearth department there in 1928 and assistant chief metallurgist in 1932. He has been assistant general superintendent at Homestead since 1937.

Howard G. McIlvried succeeds Malcolm F. McConnell as general superintendent of the Carnegie-Illinois Steel Corporation's Homestead Works. Mr. McIlvried, who has been general superintendent of Irvin Works since its construction in 1938, has been associated with United States Steel Corporation subsidiaries since 1902. He held various engineering positions with the former American Sheet and Tin Plate Company and was chief engineer of that company from 1931 to 1933. He was appointed assistant manager of operations, Chicago district, of Carnegie-Illinois Steel Corporation in 1936 and came to Pittsburgh a year later during construction of Irvin Works.

Laurence S. Dahl has been appointed general superintendent of the Carnegie-Illinois Steel Corporation's Irvin Works. Mr. Dahl became associated with subsidiary companies of United States Steel Corporation at Gary, Indiana, in 1927. He succeeded to various operating positions at Gary, becoming superintendent of the hot strip mills in 1936. He was named assistant general superintendent of the new Irvin Works on November 1, 1937.

Malcolm F. McConnell, formerly general superintendent of the Homestead Works, Carnegie-Illinois Steel Corporation, has been appointed as manager of technical development for the same company. Mr. McConnell, who has been associated with subsidiaries of the United States Steel Corporation since 1905, has been general superintendent of the Homestead Works since 1933. He had previously been general superintendent at the Mingo Junction, Ohio, plant of the former Carnegie Steel Company. Mr. McConnell received the honorary degree of doctor of science from his alma mater, the University of Pittsburgh, in 1937.

John H. Elliott has been appointed assistant general superintendent of the Irvin Works of the Carnegie-Illinois Steel Corporation, succeeding Laurence S. Dahl, the new general superintendent. Mr. Elliott studied engineering at the University of Pittsburgh and in 1919 joined the engineering department of the former American Sheet and Tin Plate Company at its Pittsburgh office. He became associated with Shenango Works of that company at New Castle, Pennsylvania, as combustion engineer in 1926. Mr. Elliott succeeded to various operating positions and in 1937 was named assistant general superintendent of Shenango Works. He transferred to the new Irvin Works as division superintendent of tin finishing, August 1, 1937. He has been assistant to general superintendent at Irvin since August 1, 1939.

Joseph H. Carter, operating vice-president of the Pittsburgh Steel Company, has been elected operating vice-president of the Sharon Steel Corporation, Sharon, Pennsylvania. Mr. Carter has been dividing his time between Youngstown and Sharon for several weeks.

From 1916 to 1936, Mr. Carter was a Youngstown resident, going there as a slagger with the former Youngstown Iron and Steel Company at Lowellville, Ohio, in 1916. The next year the company was bought by Sharon Steel Hoop Company, and he began working up through the open hearth department, being made assistant superintendent in 1919, and open hearth superintendent two years later. In 1926 he was named assistant works superintendent, and four years later works superintendent. In March, 1936, he was transferred to Pittsburgh as general superintendent of the Pittsburgh Steel Company. Two years later he became operating vice-president of Pittsburgh Steel.

JAMES W. KINNEAR, JR.

HOWARD G. McILVRIED

LAURENCE S. DAHL

George E. Hitchens, assistant to vice-president in charge of operations, National Tube Company, Pittsburgh, Pennsylvania, recently retired after fifty years of continuous service. Mr. Hitchens was born in La Salle, Illinois, and came to McKeesport, Pennsylvania, with his parents in 1890. He started to work with the National Tube Company as a waterboy, when he was sixteen years old. In a few months he became a tube measurer. In 1893 he was promoted to shipping clerk, and seven years later was made a steel blower. He was promoted to superintendent of the Bessemer division of the steel department in 1906, and ten years later became superintendent of the entire steel department. He was made assistant general superintendent in 1930, and was elevated to general superintendent in 1933. He held that post until last year when he was made assistant to the vice-president in charge of operations.

When speeds run high - -

When motor speeds run high or for any other application where a rigid winding is required, DOLPH'S SYNTHITE No. 153-Y Clear Baking Varnish provides a dependable solution.

Compounded from synthetic gums, this remarkable insulating varnish provides an extremely hard finish—one that holds windings rigid, prohibiting all possibility of coil movement at high speeds.

There must be several units in your mill where a conventional insulating varnish does not seem to meet all requirements. Why not have your electrical staff tell us about them? Perhaps SYNTHITE No. 153-Y would be the answer. We will gladly cooperate with your engineers without obligation.

JOHN C. DOLPH CO.

Insulating Varnish Specialists

166A Emmett Street Newark, N. J.

L. E. Block has retired as chairman of the board of directors of Inland Steel Company, Indiana Harbor, Indiana. Mr. Block has been associated with Inland Steel Company continuously since 1897. For more than twenty years, Mr. Block has been chairman of the board of directors, and prior to this time he was a vice-president of the company. He served for many years as a director of the American Iron and Steel Institute, and on his retirement last year was elected honorary vice-president of the organization.

Edward L. Ryerson, Jr., has been elected chairman of the board of directors, Inland Steel Company, Indiana Harbor, Indiana. Mr. Ryerson has been vice-chairman of Inland Steel since the acquisition of Joseph T. Ryerson and Son, Inc., by Inland in 1935. Mr. Ryerson was associated since 1909 with the Ryerson Company, which was founded by his grandfather in 1842. He was president of that company from 1929 until 1937 and has since been chairman.

James C. Morgan has been promoted to general manager of the entire Philadelphia plant of Yale and Towne Manufacturing Company. Mr. Morgan, who has been general sales manager, first became associated with the Yale and Towne Manufacturing Company in 1920 when he went to Stamford from the C. B. Hunt Company, to take charge of Yale's electric truck sales.

W. C. Swalley was made assistant general sales manager of the Wellman Engineering Company, Cleveland, Ohio. In addition to handling the sales of clamshell and dragline buckets, he assumes the broader duties of assisting in the sale of all Wellman engineered equipment.

Roland Whitehurst has been appointed assistant general sales manager for the Electric Storage Battery Company, Philadelphia, Pennsylvania. Mr. Whitehurst, who was manager of the Washington branch, will be succeeded by J. A. Klingensmith.

Frank A. Garvey, assistant superintendent of the Union Drawn division of Republic Steel Corporation, Cleveland, Ohio, has been promoted to superintendent of that division.